AFIT/GSO/ENY/99M-01

A STATISTICAL ANALYSIS
OF SPACE STRUCTURE
MODE LOCALIZATION

THESIS

Amy M. Cox
Second Lieutenant, USAF

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THESIS

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Amy M. Cox, B.S.

Second Lieutenant, USAF

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Amy M. Cox, B.S.

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Approved:

Captain Gregory Agnes Thesis Advisor	8 Mar 99 Date
Doctor Anthony Palazotto Committee Member	3/5/99 Date
Major Jeffrey Turcotte Committee Member	5 Mar 99 Date

Preface

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List of Abbreviations

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Abstract

Cyclic structures, such as antenna arrays, multi-bay trusses, and compressor blades, are significantly impacted by slight changes to system periodicity. Manufacturing errors of 5% or less can result in drastic changes to a structure's modal behavior. This change in modal behavior is significant, since it may result in the focusing of modal energy to individual substructures of the system. Poor modal identification can result in poorly designed control systems, resulting in shape control and pointing issues for space antennae. Additionally, modal energy localization may damage individual system components due to unanticipated levels of cyclic loading, leading to high cycle fatigue.

In this study, the effects of varying the levels of system mistuning on mode localization is investigated. A test article representative of a space antenna has been constructed and its modal properties determined for various levels of both mistuning and inter-structure coupling. Also, two simple numerical models have been considered and Monte Carlo simulations have been conducted with various levels of mistuning and inter-structural coupling for each. The objective is to determine the probability and severity of system localization as a function of the system substructure imperfections. Additionally, reduction of mode localization through the addition of passive control to the system by way of piezoceramic materials is investigated.

Experimental results for the test article, for all levels of inter-structure coupling, demonstrate that the mean mode localization increases with increasing system mistuning level. Mistuning sets, with similar statistical characteristics, were found to generate varying levels of localization. The level of inter-structure coupling affected the degree of system localization, however, the trend observed was not as anticipated. Targeted localization of the first and last mode of the first modal band was also observed in the experimental results.

The numerical results for the system indicate that the mean mode localization increases with increasing system mistuning level. Due to the increased number of mistuning sets considered for the numerical results, the behavior of the standard deviation of the

localization was observed. The trend of the localization standard deviation was found to be altered significantly by system coupling. Higher coupling levels improved the likeliness of low localization for high levels of system mistuning.

The addition of piezoceramic coupling, through means of parallel wiring alone, was ineffective in reduction of localization. Alternative methods of utilizing piezoceramics, in the reduction of localization, are still worthy of investigation.

A STATISTICAL ANALYSIS OF SPACE STRUCTURE MODE LOCALIZATION

I. Introduction and Overview

Previous research assumed that simple models could analyze cyclic structures. Slight imperfections were not considered in the models, because it was thought that they would not greatly effect the overall modal behavior of the system. The assumption of periodicity is also quite attractive for the simpler numerical computations it allows. Unfortunately, it has been found that small periodicity breaking errors have the capability of significantly altering the expected behavior of a system.

The effects of imperfections on space-like structures are considered in this thesis. Additionally, methods of decreasing adverse effects of these imperfections are investigated.

Background

Mode localization is the phenomena where the global modes of a cyclic system are altered due to slight differences between the individual components of the structure. Imperfections on the order of five percent, but within manufacturing tolerances, have been shown to cause mode localization and deformation [15]. This results in focusing the otherwise distributed vibration energy to specific portions of the cyclic structure or, in the extreme, to an individual sub-structure.

Space structures, such as large antennae and booms, fall into the category of cyclic structures that are susceptible to this phenomena [5],[15]. Unanticipated mode localization can result in poor models of space structures and hence in poor shape control. This is particularly detrimental to missions such as large space telescopes. Also, control issues may result in pointing difficulties. Station keeping fuel may be expended to counteract this effect; causing a reduction in a spacecraft's effective lifetime. Finally, shortening of

material life and potential catastrophic failure can result due to unanticipated levels of cyclic loading. On a positive note, the effects of mode localization could potentially be used for beneficial means, such as confinement of vibration energy to a specific part of the structure, preventing disturbances to others.

A considerable amount of research has been conducted in the study of this phenomenon. Early research was conducted in the field of solid state physics, where periodicity-breaking imperfections in crystal lattices were found to affect the performance of metallic conductors[1]. Study has also been conducted in the field of aircraft engine turbine blades. The mistuned blade problem has had significant levels of research due to the effect of blade damage on aircraft engine operating lifetime. Research on the effects of localization in space structures began in the mid-eighties. Numerous analytical, numerical and experimental studies have been conducted since that time. These studies will be the subject of the following discussion of the effects of various parameters on the mode localization phenomena.

Defining Localization. A key part of studying mode localization is being able to quantify its occurrence. When does a mode transition from a global to a localized state? One method of determining localization is comparison of the peak deflections of the individual structures [20]. This method entails finding the values for the peak deflections of each cyclic substructure and then scaling them by the maximum deflection. If any of those values are less than say ten percent, localization is occurring. This method was utilized by Pierre, Tang and Dowell in their study of multi-span beams [20].

Another method is to consider the modal length scale. Cornwell and Bendiksen utilized a modal length scale, similar to length scales considered in solid state physics, to determine localization in a radial rib reflector [9]. Their length scale can be shown to be a combination of the two norm and the four norm of a given mode shape's deflections at a specific distance from the center of the radial rib reflector. The length scale can be seen in Equations 1.1 and 1.2.

[1] Anderson and Mott, winners of the Nobel Prize in 1977 [5]

$$\Lambda_{kfour}(x) = \frac{(\sum_{i=1}^{N} \nu_i^2(x))^2}{\sum_{i=1}^{N} \nu_i^4(x)} = \frac{(||\nu_i(x)||_2)^4}{(||\nu_i(x)||_4)^4} \tag{1.1}$$

$$L_{four}(x) = \frac{\Lambda_{kfour}(x)}{\Lambda_{0kfour}(x)} \tag{1.2}$$

For this length scale, x indicates a position along the length of an element, k indicates a specific mode, N is the number of cyclic elements and ν is the deflection at a specific point. The zero subscript indicates calculations for the ordered mode (of the corresponding perfect structure). Further discussion of norms is covered in Chapter 2.

Unlike the method described by Pierre, Tang and Dowell, this method does not have a specific point at which a mode is considered localized. This value is unity for ordered modes and is small, about 0.3 or lower, for localized modes. It is up to the users' discretion to determine what is localized. This value is useful in that it is normalized by the ordered modes, and yields values typically between one and zero. It should be noted that this scale can yield values greater than one in situations when the system disorder causes the modes to be further extended than those of the perfect system [16]. The common scale from one to zero allows one to compare dissimilar modes on the same scale.

The reader may wonder how the global modes of a system may become further extended. Individual substructures of a cyclic structure may exist at the nodes of some of the structures modes. Those modes, although global, appear localized to some degree; some of the structures are deflecting while others remain still. Through the addition of mistuning those once nodal substructures are experiencing deflection. Hence, energy is further distributed throughout the system and the global system becomes further extended.

Further discussion of localization determination methods will be covered in Chapter 2. Specifically, the four norm/two norm method utilized by Bendiksen [5] and two parameters developed for consideration here: an Infinity/Two norm scale and a Modal Assurance Criteria (MAC) based scale.

Modal Bands Definition. Before proceeding with further discussion, it is important to define modal bands, as they will be used for many of the following descrip-

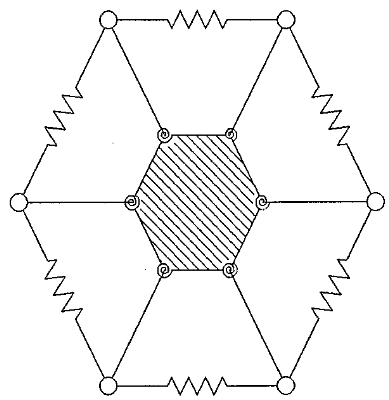


Figure 1.1 Example Antenna Array

tions. For a cyclic structure, such as the antenna shown in Figure 1.1, there is one modal band. Each band correlates to a specific cantilever bending mode. For the first band, each of the ribs is deflected in the first cantilever bending mode, the second band is the second bending mode and so on. There are as many modes in each band as there are substructures. For the antenna shown in Figure 1.1, there are six modes for each band. The first mode in a band occurs when all of the antenna ribs are in phase with one another. For the case of the first band, this is called the umbrella mode. The last mode of the band occurs when all of the ribs are 180 degrees out of phase with their adjacent ribs.

Modal Bandwidth Definition. Another important concept for the discussion of localization is modal bandwidth. How susceptible a system is to localization can be determined through calculation of the modal bandwidth of the ordered structure. The modal bandwidth is a relation between the minimum and maximum modal frequencies of a specific band. It can be calculated with Equation 1.3 for a specific mode k [5],[15].

$$\Delta\lambda_j = \frac{\omega_{max,j}^2 - \omega_{min,j}^2}{\omega_{min,j}^2} \tag{1.3}$$

Continuing with the example array shown in Figure 1.1, there are 6 modes for each of the modal bands. Through considering the number of modes per band and the modal bandwidth, one obtains a measure of modal density (i.e. the number of modes per band divided by the bandwidth). The higher this modal density, the more likely localization is

to occur [9]. Increasing this bandwidth could have an overall effect of reducing localization susceptibility.

The effects system parameters have on modal bandwidth and hence on localization will be discussed in the following section. It should be noted that other methods for determining the likelihood of localization have been considered but will not be discussed in this study.

Individual Parameter Effects on Localization

Various physical parameters effect a system's periodicity. Mistuning in these parameters can enhance or decrease the mode localization phenomena. Previous studies on the effects of the following parameters will be discussed in this subsection. The parameters to be discussed include:

- Degree of Inter-Component Coupling
- Number of Cyclic Structures
- Mass
- Substructure Stiffness
- Forcing Type
- Structure Coupling Location
- Miscellaneous Factors

Each of these items is discussed in the following subsections.

Degree of Inter-Component Coupling. The level of inter-coupling present in a system significantly affects localization. This concept is intuitive in that, if infinite coupling existed amongst substructures, the result would be a single structure acting as one. However, if little or no coupling exists, the system components act independent of one another. Keeping this in mind, the higher the level of inter-component coupling, the less likely localization is to occur.

Levine-West and Salama [15] conducted experiments on a space-like structure and showed this to be true. The specimen they analyzed was a twelve rib antenna with coupling located at the tips and midpoints of each rib. They found that lower modes which experienced localization at low levels of coupling were further extended/non-localized as the coupling level increased. Higher modes still experienced degrees of localization. They were limited in the level of coupling they could utilize due to the buckling effects higher coupling would have on their test specimen.

Number of Cyclic Substructures. The number of substructures that a cyclic structure is composed of also impacts the structure's susceptibility to localization [5],[7]. It was found in analytical and numerical studies of wrap rib antennae that, as the number of cyclic substructures increases, the structures become increasingly sensitive to mistuning of periodicity [5],[7].

Bendiksen considered two single degree of freedom systems numerically, one with 48 substructures and the other with 100 substructures. When both systems were mistuned it was found that the 48 substructure system was less susceptible to localization.

Cornwell and Bendiksen followed up this study with one that numerically considered multi-degree of freedom systems. Similar conclusions resulted from this study. The analysis completed by Cornwell and Bendiksen was accomplished with a numerical model that was based on a Rayleigh-Ritz formulation using the first five cantilever beam bending modes and a finite element formulation using Bernoulli-Euler beam elements [7]. Of interest with this system was that instead of considering a flat antenna structure, this system had a cone angle α. Two structures were considered, one with 18 ribs and the other with 48. Localization did not occur in the first band for the 18 rib structure, however, it occurred in a few of the first band modes of the second structure. It appeared that if a mode was already localized in the 18-rib structure, it remained so in the 48-rib structure. However, some of the non-localized modes in the 18-rib structure became localized when the number of structures increased to 48.

In addition to the analysis of the mode shapes, Cornwell and Bendiksen considered the time response of two systems. The time response of both a 40-rib and a 100-rib system

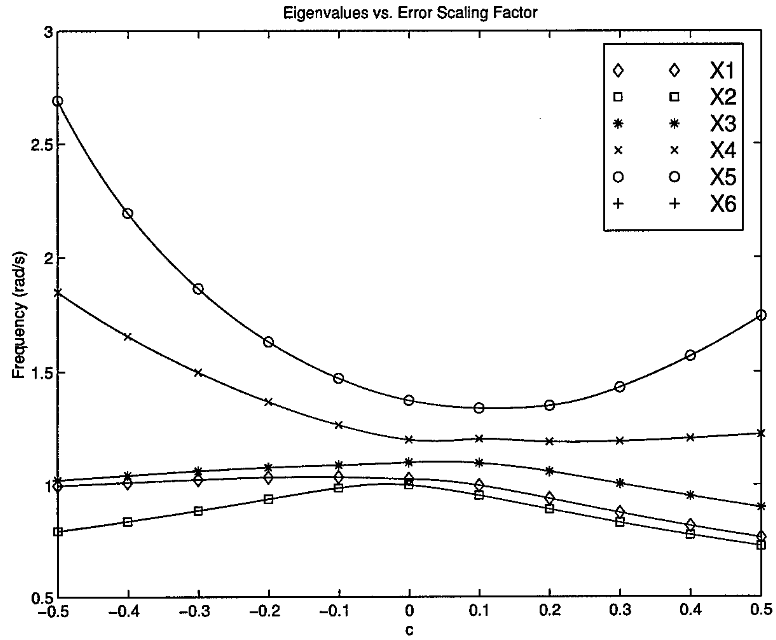


Figure 1.2 System Eigenvalue Behavior for Varying Mistuning Strength

to an impact were considered. Both systems were randomly mistuned with values from similar distributions. It was found that the wave was significantly more confined with the increase in the number of structures.

Mass. Brasil and Mazzilli [6] utilized both a simple Lagrangian and a numerical model to study the effects of disordered mass loading on triggering the localization of cyclic systems. They considered two systems; the first, a two pendulum, single degree of freedom per pendulum system, and the second, a six pendulum, single degree of freedom per pendulum system.

It was found with the two pendulum system that the eigenvalues for both modes were found to veer about the point of zero mass error as mass error strength ranged from $\pm 5\%$. This effect was duplicated, to some extent, for the open ended pendulum system discussed in Chapter 2. The eigenvalue behavior of that system, for all six eigenvalues, is shown in 1.2. The normalized displacement of the masses for both the first and second modes were found to experience sharp changes as error was added about the zero point.

For a pseudo random mistuning pattern with a mean of zero and a variance of one, severe localization was observed in the six pendulum system. For all of the modes only one mass experienced the majority of the displacement.

Additionally, for the two pendulum system, it was noted that the eigenvalues were found to decrease as a function of increasing loading mass when no error was added. From their work it can be seen that the addition of mistuning mass that has a mean, μ, and a variance, v, results in a decrease in the eigenvalues and a localization of the modes.

Substructure Stiffness. The effects of the structural stiffness of the substructures are inverse to those of the mass. As the individual substructures experience an increase in stiffness, the eigenvalues/frequencies increase. Mistuning of structural stiffness has much the same effects on a system as mass mistuning [19].

Mistuning of flexural rigidity has been analyzed in a Monte Carlo research effort by Pierre [19], it was also considered by Cornwell and Bendiksen [8]. For these research efforts, the stiffness mistuning was utilized as a mistuning method, and the focus of the research was not on substructure stiffness itself.

Forcing Type. Cornwell and Bendiksen [8] considered the effects of two types of disturbing forces on an 18-rib space reflector. The methods were impact and out of plane rigid body forcing (such as that which would occur when the satellite a space structure is attached to is undergoing maneuvers). These forcing methods were chosen to represent small impacts and whole spacecraft motion (i.e. maneuvering) that real world space structures experience.

For their study, the flexural rigidity of the perfect system was mistuned with random values between $\pm 2.5\%$. It was found for the impact forcing that, if the first modal group is not localized, impacts to a single rib will propagate throughout the structure even if higher modal groups are highly localized. This result occurred for different impact locations.

When out of plane excitation was utilized, it was found that the perfect structure had constant amplitude simple harmonic motion. Variable amplitude motion was experienced for the mistuned system.

In another study, Levine-West and Salama [15] found that the level of forcing can effect the degree of localization that occurs. In their specific case, non-linearities such as air drag, stiction and friction decreased the effect of mode localization.

Structure Coupling Location. As with coupling, inter-connection location is an intuitive concept. Levine-West and Salama discussed this in the introduction to their work [15]. Essentially, if inter-component connections are located at modal nodes, they are not "seen" by the structure when vibration occurs at that particular mode. However, at points where there is a significant difference in component position, coupling is most certainly "seen".

Cornwell and Bendiksen studied location of inter-connection in an 18-rib space antenna. The system's flexural rigidity was mistuned, and an individual rib of the antenna was impacted for various connection locations. It was found that regardless of where the ribs were connected, the first mode was the mode primarily excited in the other ribs.

Miscellaneous Factors. Miscellaneous factors that do not fill an individual subsection are discussed in this section. The configuration of the mistuning is of significance. In numerical studies of space-like structures, Cornwell and Bendiksen found that a different level of disorder occurred when the same mistuning set was rearranged and applied to their system [9].

Localization is more likely to occur at the beginning and end of a band. Essentially the umbrella mode and the 180 degree out of phase mode are the most susceptible to localization. This has been seen both numerically and experimentally [9],[15].

The likelihood of localization increases for higher bands. This has been seen numerically [9] and experimentally [15].

It has been seen experimentally [15] in a space antenna-like structure, that the order in which localization focuses in individual modes of a band, correlates well with the order of the individual antenna-band natural frequencies. Essentially, when individual antenna ribs were ordered by their natural frequency, it was found that the modes, in order of frequency, were most localized about the antenna rib that lied in the same frequency order.

Statistical Analysis on Mode Localization

Extension and localization of modes can occur for similar mistuning sets [16]. Due to this, the occurrence of localization, or the degree to which it occurs appears, to be statistical in nature. Through literature search, two pertinent Monte Carlo analysis were found to have been conducted.

In the first of these, Pierre utilized Monte Carlo simulation to verify modal and wave based perturbation calculations of a localization parameter[19].Pierre studied the effects of stiffness disorder on the propagation of vibrational energy throughout a system of coupled pendulums. The localization parameter he considered was an exponential decay coefficient, γ, that demonstrated how well modal energy was transmitted throughout the system. His coefficient γ was zero for ordered systems in frequency regions defined as passbands. This zero value indicated that modal energy was passed throughout the system without dissipation or reflection. However, γ values were shown to increase and cause a dissipation of energy transmission in the passbands when disorder was added to the system.

The second analysis, conducted by Lust, Friedman and Bendiksen [16], compared the maximum, minimum, and average localization parameters obtained from the Monte Carlo runs for the modes of multi-span beams and multi-bay trusses. A result of particular interest was that one of the Monte Carlo runs conducted resulted in the overall extension of a mode.

Numerical and Experimental Study Overview

This thesis has two principle purposes, they are:

1. To show statistically how the degree of localization varies as the system mass mistuning variance increases.
2. To experimentally determine how the degree of localization is effected with the addition of piezo-electric coupling to a real system.

To accomplish the first purpose, both numerical and experimental studies were conducted. The numerical study examines the effects of increasing mistuning mass on two simple models. These models are:

1. A six, single degree of freedom pendulum system with the ends of the first and last pendulums disconnected, similar to repeated structures discussed in [6]and [19].
2. A six, single degree of freedom pendulum system with the ends of the first and last pendulums connected. A simplified model of the experimental structure considered in Chapter 3.

Since it has been observed in existing research that localization or extension of the system modes occurs for the same levels of mistuning, the study of localization for varying levels of variance must be a statistical analysis. To these means, a Monte Carlo analysis has been conducted for each system. The study of the Monte Carlo results yields a statistical measure of the probability of localization occurrence for each system at the various mistuning levels. Additionally, the Monte Carlo runs have been conducted for three levels of inter-pendulum coupling, one tenth of nominal, nominal and three times nominal.

Statistical experiments to a much smaller degree were conducted on a test specimen. The test specimen under analysis is a cyclic structure consisting of a hexagonal plate and six nearly identical metal strips, each clamped to the sides of the plate. This system represents a cyclic space antenna-like system. The individual metal strips (antenna ribs) have been mistuned with multiple sets of clamp-on mistuning masses at three levels of inter-rib coupling.

This same test specimen primarily satisfies the second objective of this thesis: the study of the effects of piezo-electric coupling on the reduction of the mode localization phenomena. For all of the inter-rib coupling levels, two levels of piezo-electric coupling have been considered. These levels are:

1. No tip to tip coupling
2. Tip to tip coupling

The test specimen has two pieces of piezo-electric material attached at the base of each rib. The first piece is utilized to excite each rib, the second piece can remain inactive or be coupled to the pieces on the other ribs. The piezo-electric material deflects when given an input voltage and gives a voltage when subject to a deflection. This electro-mechanical property of this material is utilized to transmit deflection energy electrically through the coupled pieces of piezo-electric material. This enhanced inter-rib coupling through electro-mechanical means will be shown to effect modal behavior in the various configurations of the test specimen.

Thesis Overview

The setup and results of both the numerical and experimental studies can be found in the remainder of this thesis. Chapter 2 of this thesis will cover the numerical portion of the thesis objectives. This includes a development of the equations of motion for each of the three models, the Monte-Carlo simulation and the some of the raw results. More detailed discussion of the results from Chapter 2 will be included in Chapter 4. The computer code for the Monte-Carlo simulations will be included in Appendix A.

Chapter 3 encompasses the experimental portion of this thesis. Discussion of the test array, equipment utilized, the experimental procedure, analysis methods and the basic experimental results will be included here. As with Chapter 2, detailed discussion of the results from the experimentation in Chapter 3 is discussed in Chapter 4. Additionally, further details on the raw results can be found in Appendix B. Appendix B has been developed to both prevent distraction from discussion in Chapters 3 and 4 and to provide more detailed information for the interested reader.

As has been eluded to, Chapter 4 is a compilation and discussion of the results of both the numerical and experimental studies conducted. In addition to a thorough discussion of the results, lessons learned and opportunities for further research are discussed.

II. Numerical Model and Experiment

This chapter focuses on the first purpose of this thesis; study of localization behavior as system mistuning standard deviation increases.

For the purpose of this study, the effects of mode localization on two simple systems have been considered numerically. These systems are a six pendulum system with open ends and a six pendulum system with the ends connected. Presented here are the models, their equations of motion, the Monte Carlo simulation setup and theory and the preliminary results of the simulations. Mode localization measurement parameters are also considered.

As part of the Monte Carlo simulation, quality control effects are considered. For the simulations completed, a quality control algorithm was incorporated. The localization behavior with and without this effect is compared in this chapter.

Six Pendulum System

The first system considered is a six pendulum system with open ends as seen in Figure 2.1. The repeated pendulum system appeared in the research [6] [19]. It was considered a good system to start with for orientation with the localization phenomena. This particular system, considered in its nominal configuration, has a substructure point mass of 1, a base rotational stiffness of 1 and an inter-pendulum coupling of 0.1. Each substructure has a length of 1 and the portion between the point mass and the base of the substructure is considered to be rigid and massless.

Equations of Motion. The equations of motion for this system have been determined using Lagrangian techniques. Deflections of θ are considered for each pendulum. This allows one degree of freedom for each substructure and a total of six anticipated modes. The equations of motion are derived below.

The total potential energy, V, is a summation of the potential energy from both the base and inter-coupling springs:

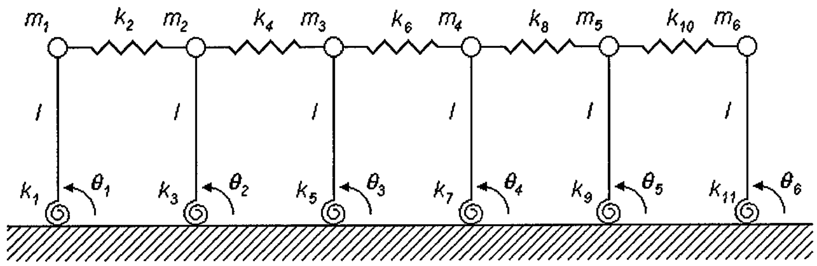


Figure 2.1 Six Single Pendulum System

$$\begin{aligned} V = & \tfrac{1}{2}k_2 l^2(\theta_1-\theta_2)^2 + \tfrac{1}{2}k_4 l^2(\theta_2-\theta_3)^2 + \tfrac{1}{2}k_6 l^2(\theta_3-\theta_4)^2 + \tfrac{1}{2}k_8 l^2(\theta_4-\theta_5)^2 \\ & + \tfrac{1}{2}k_{10} l^2(\theta_5-\theta_6)^2 + \tfrac{1}{2}k_1\theta_1^2 + \tfrac{1}{2}k_3\theta_2^2 + \tfrac{1}{2}k_5\theta_3^2 + \tfrac{1}{2}k_7\theta_4^2 + \tfrac{1}{2}k_9\theta_5^2 + \tfrac{1}{2}k_{11}\theta_6^2 \end{aligned} \tag{2.1}$$

The kinetic energy, T, is the summation of the kinetic energy of the pendulum masses:

$$T = \frac{1}{2}\sum_{i=1}^{6}(m_i\dot{\theta}_i^2 l^2) \tag{2.2}$$

It should be noted that the potential energy was linearized, arc lengths of $l\theta_i$ were considered equivalent to the horizontal tip displacements.

The Lagrangian is determined with the equations for the potential and kinetic energies shown in Equations 2.1 and 2.2 respectively:

$$L = T - V \tag{2.3}$$

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}_i}\right) - \frac{\partial L}{\partial \theta_i} = 0 \tag{2.4}$$

The necessary derivatives are taken as shown in Equation 2.4 to determine the equations of motion for the free response of the system.

The equations of motion are:

$$[M]\{\ddot{\Theta}\} + [K]\{\Theta\} = 0 \tag{2.5}$$

Where:

$$[M] = \begin{bmatrix} m_1 l^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & m_2 l^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & m_3 l^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & m_4 l^2 & 0 & 0 \\ 0 & 0 & 0 & 0 & m_5 l^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & m_6 l^2 \end{bmatrix} \tag{2.6}$$

$$[K] = \begin{bmatrix} k_1 + k_2 l^2 & -k_2 l^2 & 0 & 0 & 0 & 0 \\ -k_2 l^2 & k_3 + k_2 l^2 + k_4 l^2 & -k_4 l^2 & 0 & 0 & 0 \\ 0 & -k_4 l^2 & k_5 + k_4 l^2 + k_6 l^2 & -k_6 l^2 & 0 & 0 \\ 0 & 0 & -k_6 l^2 & k_7 + k_6 l^2 + k_8 l^2 & -k_8 l^2 & 0 \\ 0 & 0 & 0 & -k_8 l^2 & k_9 + k_8 l^2 + k_{10} l^2 & -k_{10} l^2 \\ 0 & 0 & 0 & 0 & -k_{10} l^2 & k_{11} + k_{10} l^2 \end{bmatrix} \tag{2.7}$$

Analysis of the perfect system yields the eigenvectors shown in Figure 2.2.

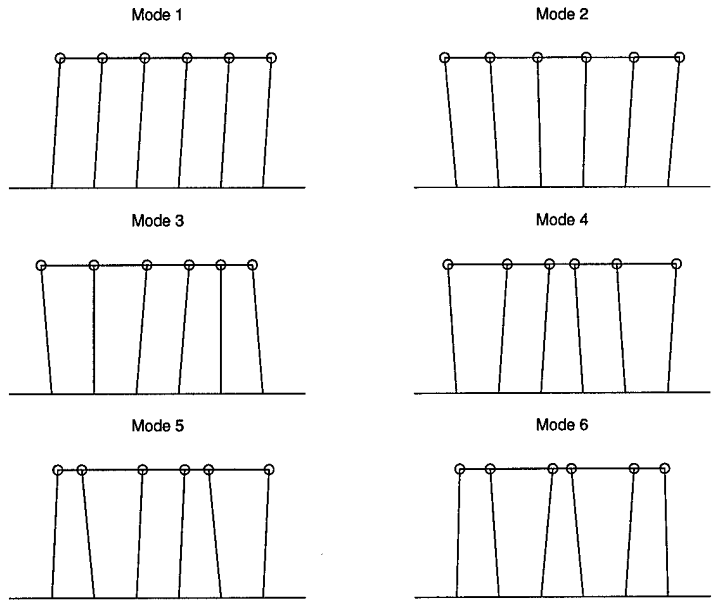


Figure 2.2 Mode Shapes For The Open Ended Six Pendulum System

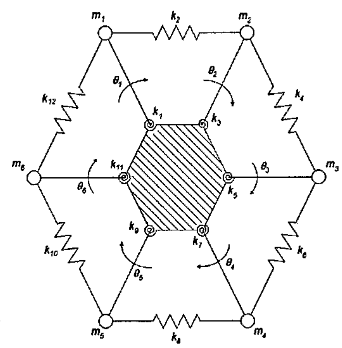


Figure 2.3 Circular Six Pendulum System

Circular Six Pendulum System

The circular six pendulum system considered is shown in Figure 2.3. This system is a circulant repeated structure. System parameters considered in this model are mass, coupling stiffness, base stiffness and length. The system has been set up so that the ratio of the coupling stiffness to base stiffness is one tenth, allowing the system to replicate a lightly coupled system. The nominal values for mass, length, coupling stiffness and base stiffness are 1, 1, 0.1 and 1 respectively. This particular simple system was selected due its similarity, in geometry, to the experimental structure considered in Chapter 3.

Equations of Motion. The equations of motion for this system have been determined in the same manner as those for the six open-ended pendulum system. The vectors referenced in Equations 2.8 though 2.10 are shown in Figure 2.4.

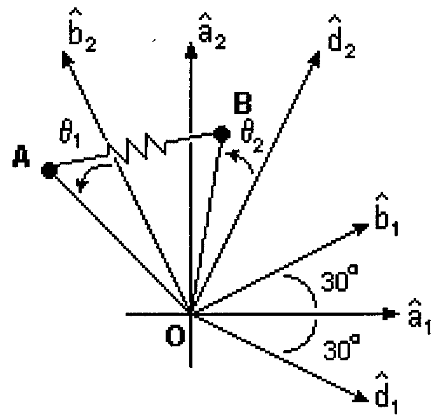


Figure 2.4 Diagram of Vectors Utilized In EOM Derivation

To determine the kinetic energy of the system, the total spring deflection was required. To find deflection, the distance between two adjacent pendulum tips was determined. The total spring deflection is equal to the magnitude of this distance minus the unstretched length of the spring (the same length as the pendulums in this situation due to the equilateral triangle formed by the two pendulums and the spring when the spring is unstretched). The total deflection is determined in Equations 2.8 through 2.13.

$$\begin{aligned}\vec{r}_{AO} \quad &= -l\sin\theta_1\hat{b}_1 + l\cos\theta_1\hat{b}_2 \\ &= -l\cos(\theta_1 + 30°)\hat{a}_1 + l\cos(\theta_1 + 30°)\hat{a}_2\end{aligned} \tag{2.8}$$

$$\begin{aligned}\vec{r}_{BO} \quad &= -l\sin\theta_2\hat{d}_1 + l\cos\theta_2\hat{d}_2 \\ &= -l\sin(\theta_2 - 30°)\hat{a}_1 + l\cos(\theta_2 - 30°)\hat{a}_2\end{aligned} \tag{2.9}$$

$$\vec{r}_{AB} = [-l\sin(\theta_1 + 30^\circ) + l\sin(\theta_2 - 30^\circ)]\hat{a}_1$$
$$+[l\cos(\theta_1 + 30^\circ) - l\cos(\theta_2 - 30^\circ)]\hat{a}_2 \tag{2.10}$$

$$\begin{aligned} |\vec{r}_{AB}| &= \sqrt{2}l\,[1 - \cos(\theta_1 - \theta_2 + 60^\circ)] \\ &= 2l\sin\left(\frac{\theta_1 - \theta_2}{2} + 30^\circ\right) \\ &= 2l\left[\sin\left(\frac{\theta_1 - \theta_2}{2}\right)\cos 30^\circ + \cos\left(\frac{\theta_1 - \theta_2}{2}\right)\sin 30^\circ\right] \end{aligned} \tag{2.11}$$

If one assumes small values of θ_1 and θ_2, a linear relationship between the stretched length of the spring and θ_1 and θ_2 can be written.

$$|\vec{r}_{AB}| \approx l(\theta_1 - \theta_2)\frac{\sqrt{3}}{2} + l \tag{2.12}$$

Next, the the unstretched length of the spring, l, is subtracted yielding the total deflection ΔX:

$$\Delta X = \frac{3}{8}l(\theta_1 - \theta_2) \tag{2.13}$$

This value for the total deflection of the springs is utilized, yielding the following relation for the total potential energy:

$$\begin{aligned} V = \frac{3}{8}&\left[k_2(\theta_1 - \theta_2)^2 + k_4(\theta_2 - \theta_3)^2 + k_6(\theta_3 - \theta_4)^2 + k_8(\theta_4 - \theta_5)^2 + k_{10}(\theta_5 - \theta_6)^2\right. \\ &\left.+k_{12}(\theta_6 - \theta_1)^2\right] + \frac{1}{2}k_1\theta_1^2 + \frac{1}{2}k_3\theta_2^2 + \frac{1}{2}k_5\theta_3^2 + \frac{1}{2}k_7\theta_4^2 + \frac{1}{2}k_9\theta_5^2 + \frac{1}{2}k_{11}\theta_6^2 \end{aligned} \tag{2.14}$$

The kinetic energy is the same as that for the open ended six pendulum system, the energy of the pendulum masses.

$$T = \frac{1}{2}\sum_{i=1}^{6}(m_i \dot{\theta}_i^2 l^2) \tag{2.15}$$

The mass matrix for this system is the same as that shown in Equation 2.6. The stiffness matrix, shown in Equation 2.16, is found after determining the Lagrangian and calculating the appropriate derivatives.

$$[K] = \begin{bmatrix} \frac{3}{4}l^2(k_2+k_{12})+k_1 & -\frac{3}{4}l^2k_2 & 0 & 0 & 0 & -\frac{3}{4}l^2k_{12} \\ -\frac{3}{4}l^2k_2 & \frac{3}{4}l^2(k_4+k_2)+k_3 & -\frac{3}{4}l^2k_4 & 0 & 0 & 0 \\ 0 & -\frac{3}{4}l^2k_4 & \frac{3}{4}l^2(k_6+k_4)+k_5 & -\frac{3}{4}l^2k_6 & 0 & 0 \\ 0 & 0 & -\frac{3}{4}l^2k_6 & \frac{3}{4}l^2(k_8+k_6)+k_7 & -\frac{3}{4}l^2k_8 & 0 \\ 0 & 0 & 0 & -\frac{3}{4}l^2k_8 & \frac{3}{4}l^2(k_{10}+k_8)+k_9 & -\frac{3}{4}l^2k_{10} \\ -\frac{3}{4}l^2k_{12} & 0 & 0 & 0 & -\frac{3}{4}l^2k_{10} & \frac{3}{4}l^2(k_{12}+k_{10})+k_{11} \end{bmatrix} \tag{2.16}$$

The modes of the perfect system were determined with eigenanalysis, and can be seen in Figure 2.5.

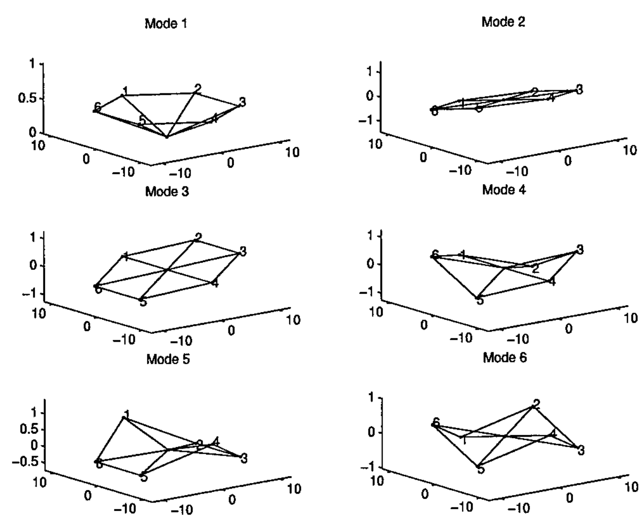


Figure 2.5   Circular Six Pendulum System Modes

Mode Localization Determination Methods. As was mentioned in Chapter 1, a method of determining localization is required. The methods considered

here include an infinity/two norm length scale, the four norm/two norm method utilized by Cornwell and Bendiksen[9] and a MAC based scale. The norm based parameters are scaled by their value for the ordered system. All of the parameters typically range from zero to one, one being global and lower than one indicating a degree of system localization. On occasion it is found that the infinity and four norm based scales exceeded one. This is indicative of a mode being further extended than the global mode.

Because two of the length scales considered utilize norms, it was felt prudent to discuss the behavior of norms. The n^{th} norm of a mode is found with the relation shown in Equation 2.17. For the relation shown, n denotes the norm taken, ψ_i indicates an individual value of a specific mode and N is the total number of values of which the mode shape consists.

$$norm_n = \frac{\sqrt[n]{\sum_{i=1}^{N} |\psi_i|^n}}{N} \tag{2.17}$$

For a given data set, lower norms are not as sensitive to extreme variance between values in the set. The values for norms as n ranges from 1 to ∞ go from the mean of the set to the absolute maximum of the set. Lower norms give a greater understanding of the whole system in contrast to high norms. However, high norms, such as the infinity norm, provide a measure of maximum deviation. Maximum deviations are of significant interest when one is attempting to control a system.

The relation for the four/two norm based scale was given in Equations 1.1 and 1.2. The infinity-two norm scale is shown in Equations 2.20 and 2.21. The MAC based scale is shown in Equations 2.22 and 2.23. It is anticipated that the infinity/two norm and four/two norm based scales should have similar behavior. An item of interest is how well the infinity/two norm scale behaves with respect to the four/two norm. It presents a significant computational advantage if it is found to provide similar system behavioral results when compared to the four/two norm.

$$\Lambda_{kfour}(x) = \frac{(\sum_{i=1}^{N} \nu_i^2(x))^2}{\sum_{i=1}^{N} \nu_i^4(x)} \tag{2.18}$$

$$L_{four}(x) = \frac{\Lambda_{kfour}(x)}{\Lambda_{0kfour}(x)} \tag{2.19}$$

$$\Lambda_{k\infty}(x) = \frac{\sqrt{\sum_{i=1}^{N} \nu_i^2(x)}}{max(|\nu(x)|)} \tag{2.20}$$

$$L_{\infty}(x) = \frac{\Lambda_{k\infty}(x)}{\Lambda_{0k\infty}(x)} \tag{2.21}$$

$$MAC_{i,j} = \frac{|{\psi_i}^H \psi_{oj}|^2}{{\psi_i}^H \psi_i {\psi_{oj}}^H \psi_{oj}} \tag{2.22}$$

$$L_{MAC} = \frac{1}{cond(MAC)} \tag{2.23}$$

For the MAC based scale, the MAC between the measured modes of the system and the global modes is determined. The MAC essentially determines the orthogonality of the modes with respect to one another. When no mistuning is added to the system, the MAC matrix is an identity matrix.

The condition number of the MAC matrix, represented by $cond(MAC)$ in Equation 2.23, is an indication of how well conditioned the MAC matrix is. Matrices that are well conditioned have low condition numbers. The identity matrix has a condition number of one, whereas the condition of a singular matrix is infinity. The more localized a system is, the more singular its MAC matrix becomes. Since one over the condition number of the MAC matrix is considered, the range of this length scale is from one to zero (zero results from one over infinity).

Monte Carlo Simulation

Background. Given a knowledge of system mistuning, say perhaps the standard deviation of component mass or dimension, one cannot deterministically state whether localization will occur. Two systems that have similar mistuning mean and standard

deviation have the potential to drastically differ in modal behavior. This is shown in Figures 2.6 and 2.7.

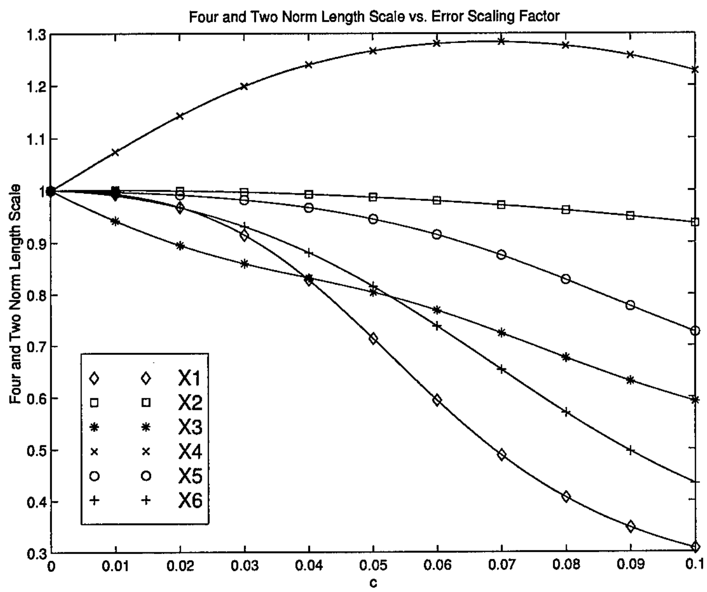


Figure 2.6 System Response to First Mistuning Set

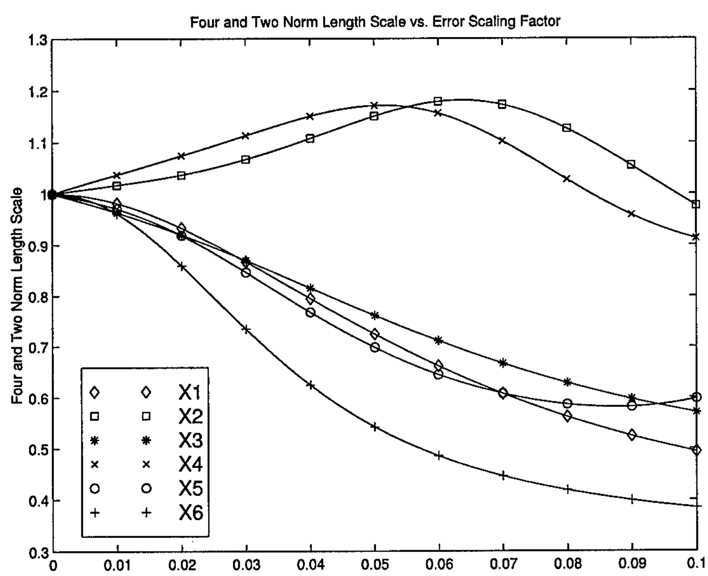


Figure 2.7 System Response to Second Mistuning Set

Figures 2.6 and 2.7 depict how the four norm/two norm parameter for the circular pendulum system varies as the mass mistuning of the system is scaled from a standard

deviation of 0 to 0.1. Both base mistuning sets utilized have a mean and standard deviation of 0 and 1 respectively. Even though the sets are similar in their statistics, there is a significant difference in their modal behavior. Mode localization severity cannot be calculated deterministically with information on mistuning statistics alone.

It has been seen that imperfections added to a system that have the same mean and standard deviation can have completely different effects on the system. These effects can range from localizing the system to further extending the system modes. This means that whether or not mode localization will occur, given a prior knowledge of system mistuning, can only be determined statistically. Due to this, a Monte Carlo simulation has been conducted. A total of 10,000 mistuning sets have been considered for 200 different variances that range from zero to 0.5. The purpose of this simulation is to see how the system is affected statistically by imperfections. This simulation provides a 99% confidence level with statistical independence of approximately 1.4%.

To trigger the mode localization phenomena the system mass has had imperfections added. The imperfections added are from a randomly generated normal distribution with a mean of zero and a variance of one. Since the mean of the imperfection set is zero, all that is required to have different variances is to multiply the set generated by the square of the variance desired. This is shown in Equations 2.24 through 2.29, where V is the variance, E is the expected value and x is the imperfection set.

$$V(x) = E(x^2) - [E(x)]^2 \tag{2.24}$$

$$E(x) = 0 \tag{2.25}$$

$$V(x) = E(x^2) \tag{2.26}$$

$$V_{new}(x) = c(V(x)) \tag{2.27}$$

Where c is constant scale value for variance.

$$V_{new}(x) = cE(x^2) \tag{2.28}$$

$$V_{new}(x) = E((\sqrt{c}x)^2) \tag{2.29}$$

A major hurdle with the Monte Carlo simulation was mode switching. As mistuning is added to a system, the order in which the mode appears changes. This can be seen graphically in Figure 2.8. The system considered in the figure is the circular six pendulum system. The six bins that span each plot represent each of the substructures. The color at a specific mistuning strength indicates the total deflection that is occurring. A scale relating the colors to the deflections is shown to the right of each plot.

For the case shown in Figure 2.8, as the scaling factor on the disorder is changed, modes 4 and 5 switch order. Due to the localization measurement methods, this position switching is critical. The measurement methods compare the disordered mode to its respective ordered mode. Comparison to the wrong mode will yield erroneous results.

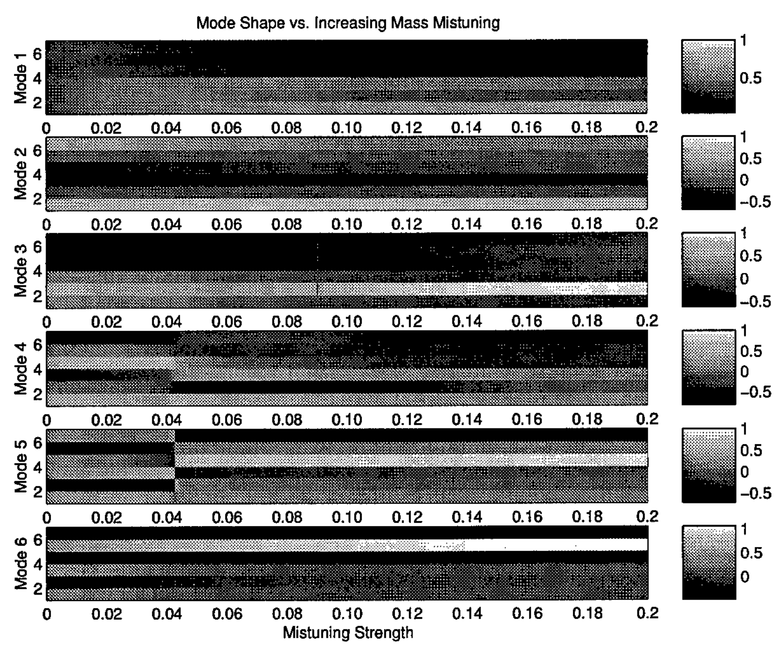


Figure 2.8 Mode Cross Over with Increasing System Disorder

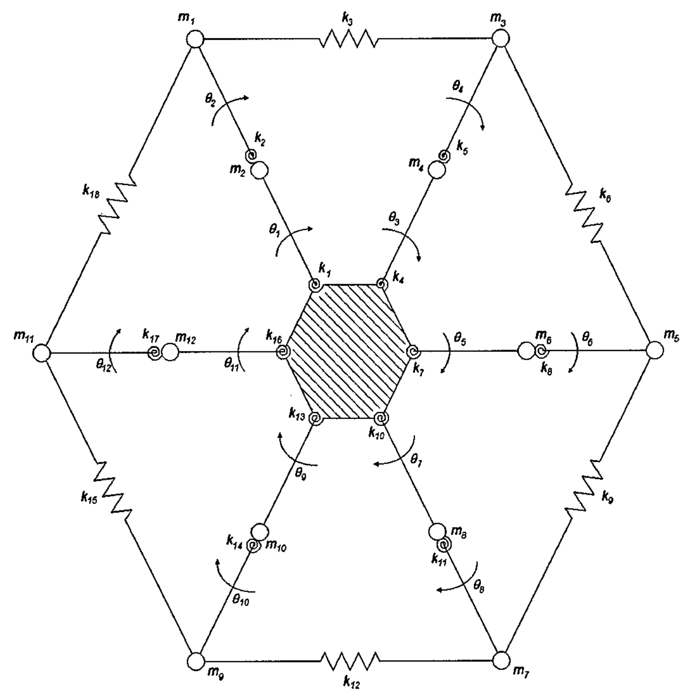


Figure 2.9 Six Double Pendulum System

To overcome the mode switching problem, a mode tracking algorithm was incorporated in the Monte Carlo code. The algorithm is described in the Monte Carlo code description that follows. Making this algorithm effective for the two systems required small step sizes between variance changes. It was found that 200 steps between 0 and 5% variance was sufficient to overcome switching for the two systems. It is important to note, a third system was attempted, a circular double pendulum system, as seen in Figure 2.9. Due to switching in that system, potentially caused by the increased degrees of freedom, 1000 steps between 0 and 1% variance were insufficient to prevent mode switching. More work in mode switching is thus required.

Algorithm. The Monte Carlo code for both systems is given in Appendix A. Detailed here is the architecture of the code and the purpose for various portions of it. The code is broken into the following sections:

1. Develop the ordered system mass and stiffness matrices

2. Gather information for the ordered system
    (a) Determine Eigenvalues and Eigenvectors
    (b) Collect the base system information for the four/two norm length scale
    (c) Collect the base system information for the infinity/two norm length scale
3. Conduct the Monte Carlo runs
    (a) Obtain user input for minimum and maximum variance, number of Monte Carlo runs, quality control rejection criteria, and number of variance steps
    (b) Start the outer loop that alters the variance, c, for the Monte Carlo simulations.
        i. Generate the random mistuning for the mass matrix, $[delm]$
        ii. Start the inner loop that allows for the Monte Carlo simulations for a specific variance.
            A. Generate a mistuning matrix for the mass matrix. The new mass matrix will be of the form $[M] + c[delm]$
            B. Determine if the set is within quality control standards
            C. Determine the disorder of the mistuning set
            D. Find the eigenvalues and eigenvectors for the mistuned system
            E. Sort the modes to prevent switching
            F. Calculate length scales for the disordered system
        iii. Loop Counter
4. Determining the histogram information for each length scale
5. Plot the results

Ordered System Development and Characteristics. The ordered system development was a fairly simple process. Depending on the system under consideration, the equations of motion derived in this chapter were utilized to develop mass and stiffness matrices. The mass and stiffness matrices were then substituted into an eigenvalue/eigenvector routine [14]. The four/two and infinity/two norm scale global system

portions were then determined with the information on the base system eigenvalues and eigenvectors.

Monte Carlo Setup. User input is obtained through a Graphical User Interface (GUI). This information specifies the parameters for the Monte Carlo simulation. User alterable parameters include: Variance range, number of Monte Carlo runs, number of variance steps and the quality control rejection value. A user may select the default values if desired. The user input values are utilized throughout the Monte Carlo runs. Outside of the run they are utilized to generate the vector of possible variance values.

Monte Carlo Runs - Main Body. The Monte Carlo simulation main body has two nested loops. The outer loop is where the mistuning is generated. This loop is repeated 10,000 times. The inner loop ramps the mistuning through the variance range. The nominal setting is for 200 steps between 0 and 5% mistuning.

Once the mistuning set is generated and multiplied by the square root of the desired variance, it is added to the ordered system mass matrix. The characteristics of this new, and disordered mass matrix are then determined. These values include: standard deviation, mean, two norm, four norm and infinity norm. These values have been determined for analysis of the localization as a function of various mass mistuning level measurements. Additionally, the mass mistuning (multiplied by the square of the variance) is run through a quality control algorithm. The algorithm finds if any of the mistuning values exceed a specific threshold (5% for this study). If the set exceeds the threshold, it is recorded as unacceptable. The set is still run through the simulation, however a quality control matrix is generated with acceptable and unacceptable marks, one for each iteration. This matrix can be utilized to remove unacceptable sets in post- processing.

After the characteristics of the mistuning mass are determined, the eigenvectors and eigenvalues of the disordered system are determined. The values were run through an algorithm to eliminate mode switching; the algorithm follows the structure described here.

1. Generate 6 base mode sets, where the columns of each base set are composed of one of the base modes, $[Base_i] = [\psi_{io}\psi_{io}\psi_{io}\psi_{io}\psi_{io}\psi_{io}]$. For the first variance step, the

base mode set is composed of the ordered system modes. For subsequent systems it is composed of the previous iteration's modes.

2. Generate 6 difference matrices $[del_i] = [[\psi_i\psi_i\psi_i\psi_i\psi_i\psi_i] - base_i\ [\psi_i\psi_i\psi_i\psi_i\psi_i\psi_i] + base_i]$. This matrix compares both the positive and negative of the generated eigenvectors to the base mode matrices. This positive/negative comparison is completed because modes also have a tendency to switch sign, an artifact of computation that does not effect the actual modal properties but does effect presentation.

3. Find the base mode that provides the minimum absolute difference between itself and the disordered system mode under consideration.

4. Reposition the mode in the eigenvector matrix based on the base mode with which it is best aligned.

5. Generate a new set of base vectors with the current set for use with the set to be generated in the next variance step.

To verify the effectiveness of this algorithm, it was applied to multiple mistuning sets that were scaled from 0 to 5%. The algorithm tracked both eigenvalues and eigenvectors for all cases observed.

With the eigenvalues and eigenvectors of the disordered set determined and sorted, it is now possible to calculate the various localization length scales. These scales are computed and the inner loop is ended. As stated before, the inner loop is completed for 200 steps, each step having a different variance value. The whole inner loop process (all 200 steps) is completed for 10,000 different mistuning sets. After all of the data for the simulation is calculated, the data is plotted in various forms.

Results

The results of the Monte Carlo simulations are next discussed. The discussion includes trends and behaviors seen. The overall significance/impact of these results is discussed in Chapter 4 along with the overall results of the experimental work completed in Chapter 3. It should be noted that, after the Monte Carlo data was generated, it was

determined that the best way to do the comparisons was to plot mistuning versus standard deviation and not variance. This only required taking the square of the variance since the overall mistuning has a mean of zero.

Localization Behavior of the Six Modes as a Function of Mistuning. Plotted in Figures 2.10 and 2.11 are the mean Four/Two Norm values for all of the modes for the two nominal systems. This is representative of the overall results for all levels of coupling. Mode one had the worst localization for all levels of coupling for the open ended system, followed by mode 4. The circulant system had behavior similar to that in the research. Its end modes, modes 1 and 6, were the most susceptible to mistuning [15].

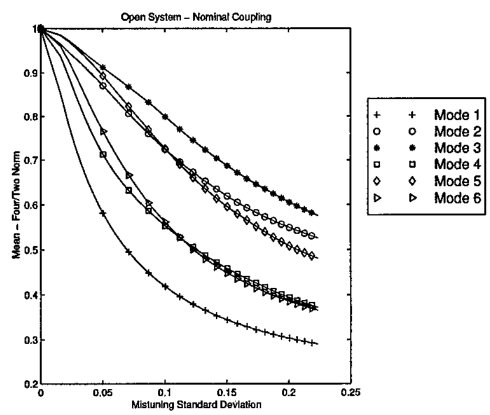


Figure 2.10 Open System Four/Two Norm Mean Versus Mistuning

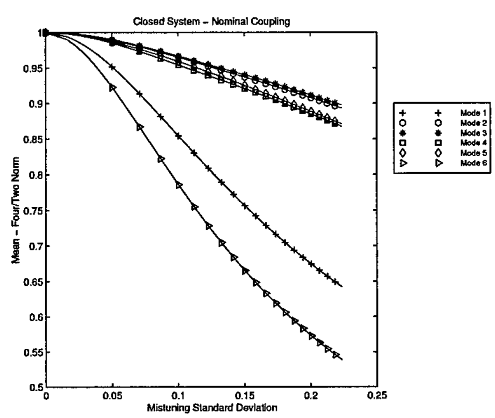


Figure 2.11 Closed System Four/Two Norm Mean Versus Mistuning

Overall, an increase in localization is seen as a function of mistuning standard deviation. More detailed results of this trend are given in the Curve Fit subsection. The actual polynomial curve fit coefficients for a relationship between mistuning and localization are provided there.

Localization Behavior of the Six Modes as a Function of Coupling. The degree of coupling affects the localization standard deviation behavior. Presented in Figures 2.12 and 2.13 are the standard deviations for Mode 1 for the various coupling levels for the two systems. The overall trend for the curves is an initial near-linear increase in the data followed by a leveling off/max which is then followed by a decrease of standard deviation.

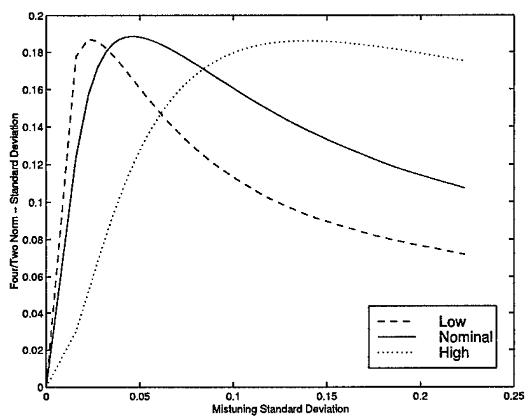


Figure 2.12 Open System Four/Two Norm Standard Deviation Versus Mistuning

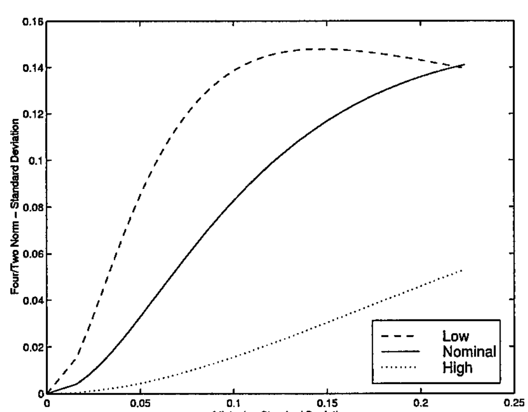


Figure 2.13 Closed System Four/Two Norm Standard Deviation Versus Mistuning

It appears that the high coupling case, at least for the circulant system, resides in the linear portion of this curve. Further investigation into higher mistuning levels may reveal the same behavior in the high stiffness case as was in the lower stiffness cases. Why the circulant system displays only the mostly-linear behavior, where the open ended system begins to level and decrease, may be caused by the additional coupling between the first and sixth pendulum of the circulant system. This additional coupling may also be the reason why the low and nominal coupling levels for the circulant system do not extend as far into the decreasing region as do the curves of the open ended system.

For all of the systems, when coupling to mistuning is low, there is a near linear increase in mistuning standard deviation. Basically, there is a wide range of possible system behavior in this region - from global to local. The system reaches a point where additional mistuning causes the overall localization to be high (i.e. less of a probability that any of the sets are global). Finally, a leveling off at low values of standard deviation occurs. What this overall trend indicates is that once the system is highly localized (i.e. experiencing high mistuning) there is not much deviation in values since all of the values are highly localized. The higher the system coupling, the higher the system mistuning must be before this 'equal badness' occurs. Coupling level stretches out the region over which this behavior occurs.

Another beneficial effect of coupling, as seen in Figures 2.14 and 2.15 is a reduction in the mean localization (an increase in the length parameter) as coupling increases. Also, it can be seen from these figures that the high coupling level for the circulant system has a lower mean localization than does the open ended system. This too is probably due to the additional coupling in the circulant system.

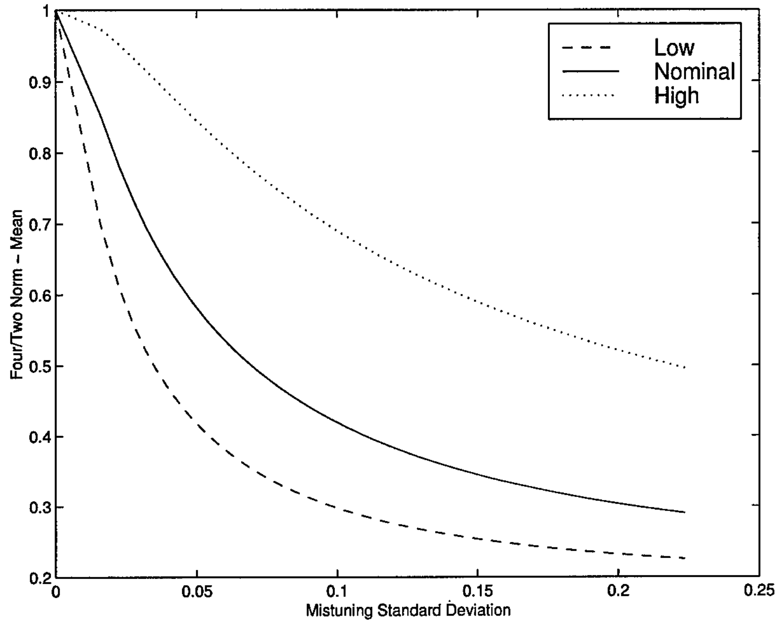


Figure 2.14 Open System Four/Two Norm Mean Versus Mistuning

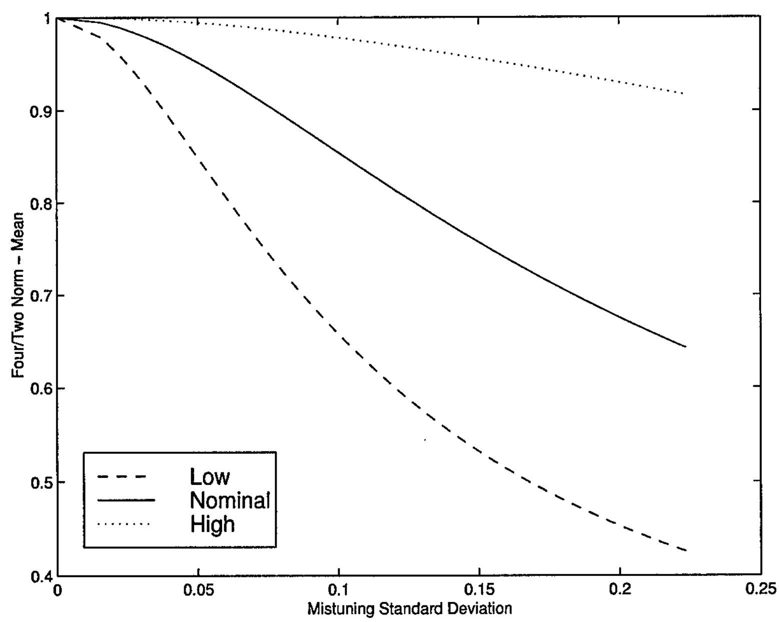


Figure 2.15 Closed System Four/Two Norm Mean Versus Mistuning

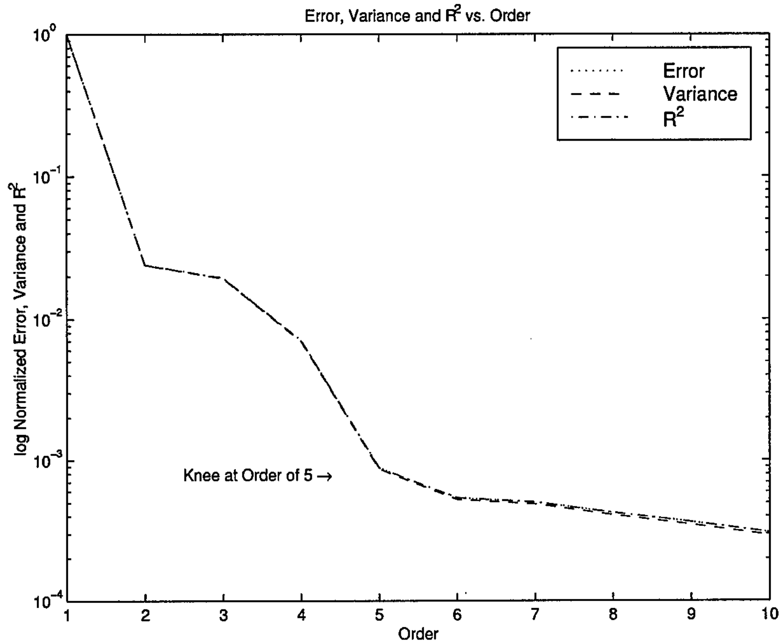


Figure 2.16 Error, Variance and R^2 Versus Polynomial Fit Order

Curve Fit Information. A relationship between the dependent variables of coupling and mistuning, and localization is desired. Since only three points are available for coupling for each system, curve fitting is not worthwhile for coupling as an independent variable. However, there is more than ample data present to determine a relationship between mistuning level (mistuning standard deviation to be more specific) and localization.

Polynomial regression was utilized to determine a relationship between mistuning standard deviation and both localization mean and localization standard deviation. To determine the optimal order for the polynomial fit, the sum of the squared error, variance and R^2 were determined for orders ranging from 1 to 20. It was found fairly early in the analysis process that 20 was excessive and that 10 was a more tractable value. The values for the error, variance and R^2 were then plotted on a log scale versus order. A sample of one of these plots for the data is shown in Figure 2.16. The optimal order is typically at the knee in the curve, for the case shown in Figure 2.16, at about an order of 5. Beyond that point, inclusion of higher order terms does not cause significant reduction in error.

It was found that, overall, a fifth order fit provided the best results for the mean localization versus mistuning standard deviation. A sixth order fit was utilized for the

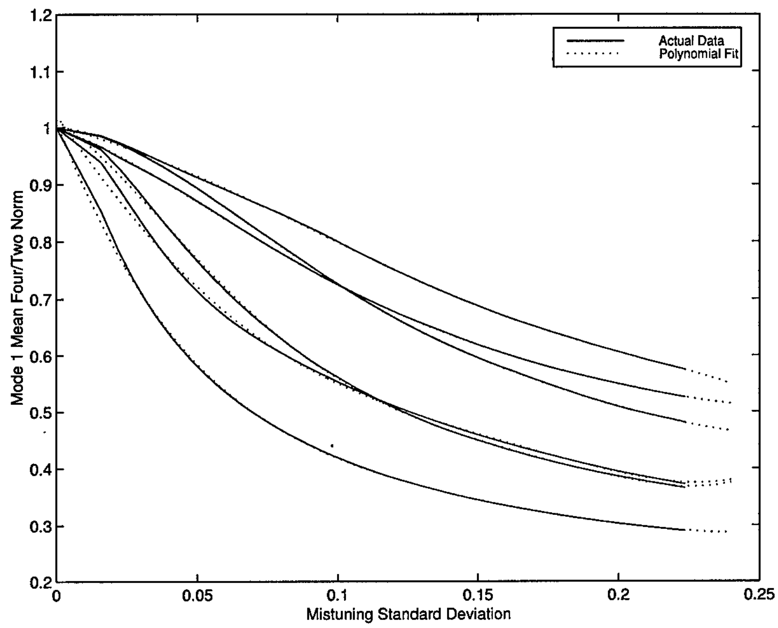


Figure 2.17   Fit Data Plotted With Actual Data

standard deviation of localization versus mistuning standard deviation. The polynomials are of the form shown in Equation 2.30, where X is the mistuning standard deviation, Y is either the mean or standard deviation of the localization and N is the order of the fit.

$$Y = P_0 X^N + P_1 X^{N-1} + ... + P_{N-1} X + P_N \tag{2.30}$$

Shown in the following tables are the order, sum of the squared error, variance, R^2 and polynomial coefficients for the curve fit for each mode of each system configuration. A sample of the curve fits accomplished is shown in Figure 2.17.

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0.0008	0	0.0004	-1117.1	1236.5	-522.08	110.74	-12.915	1.0118
Mode 2	5	0	0	0	1305.7	-1008.3	290.27	-31.266	-1.6290	0.99889
Mode 3	5	0.0002	0	0.0001	-1090.0	506.56	-43.302	-5.4837	-1.4709	1.0046
Mode 4	5	0.0027	0	0.0011	3055.4	-1593.2	221.63	14.917	-7.1361	1.0221
Mode 5	5	0	0	0	2088.2	-1652.8	495.95	-61.626	-0.079118	0.99916
Mode 6	5	0.0010	0	0.0003	5719.3	-3707.5	847.29	-66.523	-3.2208	1.0132

Table 2.1   Open Pendulum System, Nominal Coupling, Four/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0.0001	0	0.0007	-54640	45812	-15488	2694.6	-252.22	11.322	0.00058
Mode 2	6	0.0001	0	0.0011	14238	-8829.4	1596.6	64.819	-55.657	6.3600	-0.00274
Mode 3	6	0.0001	0	0.0005	60936	-4.7515	1.4309	-0.20293	0.01207	0.00001	0
Mode 4	6	0.0003	0	0.0065	-6242.6	6767.9	-2792.2	578.29	-67.258	4.5384	-0.00488
Mode 5	6	0	0	0.0002	33113	-23751	6413.4	-749.16	18.237	3.3743	-0.00004
Mode 6	6	0.0001	0	0.0012	25940	-17994	4368.0	-335.20	-28.262	5.3528	-0.00290

Table 2.2 Open Pendulum System, Nominal Coupling, Four/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0.0011	0	0.0015	-7200.4	5045.4	-1373.6	185.38	-13.450	0.98602
Mode 2	5	0.0003	0	0.0005	-1225.0	774.04	-188.23	25.934	-3.2617	0.99262
Mode 3	5	0.0002	0	0.0003	-4792.2	3216.8	-817.42	99.762	-6.9472	0.99663
Mode 4	5	0.0003	0	0.0004	-4993.3	3523.9	-966.81	132.25	-10.230	0.99389
Mode 5	5	0.0003	0	0.0004	-1030.3	547.67	-91.914	7.2309	-1.8439	0.99259
Mode 6	5	0.0002	0	0.0002	1347.7	-770.31	125.31	5.8134	-4.0280	1.0049

Table 2.3 Open Pendulum System, Nominal Coupling, Infinity/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0.0003	0	0.0093	-56165	44523	-14014	2223.3	-185.00	7.2401	0.00484
Mode 2	6	0	0	0.0013	-17468	14804	-5105.1	925.16	-94.657	5.2195	0.00060
Mode 3	6	0	0	0.0009	-2585.2	1860.6	-641.26	153.81	-26.287	2.5982	0.00113
Mode 4	6	0.0001	0	0.0048	-25113	20001	-6290.7	994.70	-84.363	3.8530	0.00185
Mode 5	6	0	0	0.0010	10676	-6102.3	1012.7	34.051	-29.028	3.2430	-0.00080
Mode 6	6	0	0	0.0006	-4953.4	5271.7	-2266.8	511.92	-65.123	4.2502	0.00034

Table 2.4 Open Pendulum System, Nominal Coupling, Infinity/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0.0014	0	0.0010	-10849	7758.3	-2168.4	301.27	-21.991	0.98704
Mode 2	5	0.0006	0	0.0002	4338.4	-2610.6	512.24	-19.670	-5.5853	1.0085
Mode 3	5	0.0002	0	0.0001	4336.3	-2919.6	706.74	-62.248	-2.1827	1.0017
Mode 4	5	0.0008	0	0.0004	-3698.8	2817.4	-867.17	141.83	-13.870	1.0070
Mode 5	5	0.0008	0	0.0003	7268.4	-4719.4	1082.0	-88.273	-2.6188	1.0102
Mode 6	5	0.0028	0	0.0012	3901.8	-2015.3	245.71	336.16	-10.214	1.0230

Table 2.5 Open Pendulum System, Low Coupling, Four/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0.0019	0	0.0134	-137729	108197	-33566	5186.9	-409.04	14.141	0.01243
Mode 2	6	0.0001	0	0.0003	-55772	47453	-16299	2889.2	-277.49	12.991	0.00137
Mode 3	6	0.0009	0	0.0067	41367	-27384	6224.7	-416.22	-41.918	6.6674	-0.00804
Mode 4	6	0.0002	0	0.0035	-29686	23816	-7719.7	1311.1	-126.43	6.5283	0.00286
Mode 5	6	0.0001	0	0.0008	9971.3	-4105.7	-496.22	523.85	-104.68	8.0488	-0.00236
Mode 6	6	0.0001	0	0.0006	-27296	25636.3	-9854.9	1973.4	-213.22	10.772	-0.00208

Table 2.6 Open Pendulum System, Low Coupling, Four/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0.0058	0	0.0106	-12854	8779.9	-2298.4	289.67	-18.248	0.96741
Mode 2	5	0.0001	0	0.0001	-772.09	679.22	-248.04	49.048	-5.8124	0.99667
Mode 3	5	0.0017	0	0.0025	-4838.05	3265.9	-847.87	109.61	-8.3072	0.98261
Mode 4	5	0.0026	0	0.0035	-8544.9	5834.3	-1533.4	197.44	-13.605	0.97828
Mode 5	5	0.0001	0	0.0002	1378.2	-908.84	196.48	-7.7131	-2.9419	0.99676
Mode 6	5	0.0002	0	0.0002	-856.82	858.62	-342.90	70.393	-7.9082	1.0053

Table 2.7 Open Pendulum System, Low Coupling, Infinity/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0.0009	0	0.0247	-80241	62511	-19194	2928.5	-227.73	7.8220	0.00846
Mode 2	6	0.0002	0	0.0061	-53917	43172	-13762	2221.0	-189.78	7.8200	0.00404
Mode 3	6	0	0	0.0008	-16351	14242	-5018.4	922.19	-94.514	5.0304	-0.00003
Mode 4	6	0.0002	0	0.0126	-28672	22790	-7224.0	1168.2	-102.46	4.5990	0.00359
Mode 5	6	0.0001	0	0.0015	-19722	16502	-5686.6	1040.7	-107.51	5.7053	0.00076
Mode 6	6	0.0001	0	0.0012	-35505	29000	-9555.7	1623.1	-148.86	6.5476	0.00176

Table 2.8 Open Pendulum System, Low Coupling, Infinity/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0.0003	0	0.0001	3718.1	-2436.1	573.48	-49.794	-1.8749	1.0074
Mode 2	5	0	0	0.0001	546.73	-294.66	58.362	-5.9195	-0.62770	1.0026
Mode 3	5	0	0	0	559.64	-419.65	117.90	-15.640	0.11957	0.99972
Mode 4	5	0	0	0	3754.3	-2672.3	695.41	-73.072	0.05561	1.0013
Mode 5	5	0	0	0	111.24	-137.26	68.188	-15.561	-0.04681	1.0000
Mode 6	5	0.0001	0	0	2507.8	-1844.1	516.14	-61.788	0.14121	1.0011

Table 2.9 Open Pendulum System, High Coupling, Four/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0.0001	0	0.0011	36927	-27985	8091.5	-1062.0	48.245	1.9718	-0.00329
Mode 2	6	0	0	0	9557.8	-8563.5	2994.6	-498.59	33.744	0.95698	-0.00010
Mode 3	6	0	0	0	-8767.8	5720.9	-1184.7	33.441	13.768	-0.03491	0.00018
Mode 4	6	0	0	0	29245	-23539	7317.6	-1073.3	67.976	-0.22600	-0.00016
Mode 5	6	0	0	0	5574.4	-4167.4	1260.5	-192.75	10.195	1.5330	-0.00002
Mode 6	6	0	0	0.0001	890.69	-2671.4	1466.8	-299.49	16.337	1.9734	0.00046

Table 2.10 Open Pendulum System, High Coupling, Four/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0	0	0	-1150.2	901.85	-291.60	52.065	-6.0895	0.99909
Mode 2	5	0	0	0.0001	-1549.4	1069.7	-276.95	33.235	-2.4183	0.99902
Mode 3	5	0	0	0	280.08	-102.80	-19.928	14.534	-2.8422	1.0001
Mode 4	5	0	0	0	-166.11	257.28	-136.83	34.887	-5.0889	1.0005
Mode 5	5	0	0	0.0001	-1171.1	804.34	-205.05	23.193	-1.8243	0.99929
Mode 6	5	0.0001	0	0.0001	1057.4	-753.45	194.79	-18.196	-1.2479	0.99775

Table 2.11 Open Pendulum System, High Coupling, Infinity/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0	0	0.0001	-9030.2	7833.2	-2807.5	540.82	-60.748	3.8292	0.00031
Mode 2	6	0	0	0.0001	-60.174	-386.12	188.31	-10.223	-8.1549	1.7653	0.00039
Mode 3	6	0	0	0.0001	-2483.4	2252.1	-814.23	149.62	-16.053	1.4218	-0.00017
Mode 4	6	0	0	0.0001	25.630	675.38	-547.00	170.08	-25.908	2.0871	-0.00017
Mode 5	6	0	0	0.0002	11535	-8341.1	2292.5	-286.06	11.052	1.1453	0.00045
Mode 6	6	0	0	0.0001	-2925.2	2100.3	-656.68	131.72	-20.886	2.2856	-0.00001

Table 2.12 Open Pendulum System, High Coupling, Infinity/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0	0	0	485.09	-461.56	173.37	-28.720	0.10256	0.99975
Mode 2	5	0	0	0	74.352	-87.139	34.599	-6.5179	0.03961	0.99976
Mode 3	5	0	0	0	213.36	-176.18	54.752	-8.4136	0.12386	0.99947
Mode 4	5	0	0	0	373.59	-279.90	79.463	-11.063	0.10520	0.99951
Mode 5	5	0	0	0	164.36	-131.37	42.336	-7.4491	0.02912	1.00012
Mode 6	5	0	0	0	1391.2	-1118.3	349.09	-47.302	0.08418	1.00018

Table 2.13 Closed Pendulum System, Nominal Coupling, Four/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0	0	0	2548.3	-2666.2	1138.4	-246.81	24.980	-0.10199	0.00012
Mode 2	6	0	0	0	-1994.2	1564.0	-435.21	44.838	-1.9053	1.0618	-0.00008
Mode 3	6	0	0	0	197.24	238.04	-170.44	24.872	-0.31317	0.79793	0.00001
Mode 4	6	0	0	0	-427.72	670.07	-255.44	23.971	0.75785	0.88957	0.00006
Mode 5	6	0	0	0	-2468.5	1859.0	-478.50	39.930	-0.98445	1.1776	0.00004
Mode 6	6	0	0	0	9532.3	-8429.5	2998.0	-530.69	42.725	-0.13118	0

Table 2.14 Closed Pendulum System, Nominal Coupling, Four/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0	0	0	-54.310	63.686	-34.727	12.100	-3.0457	1.0000
Mode 2	5	0.0020	0	0.0213	-5056.6	3345.6	-837.57	98.403	-5.7083	0.98068
Mode 3	5	0.0007	0	0.0058	3442.4	-2217.1	523.92	-54.059	1.7239	1.0113
Mode 4	5	0.0007	0	0.0047	3442.1	-2194.2	510.48	-51.465	1.4862	1.0114
Mode 5	5	0.0019	0	0.0177	-4816.1	3234.4	-824.88	98.692	-5.8089	0.98093
Mode 6	5	0	0	0	-162.19	158.71	-70.379	19.595	-3.9672	0.99996

Table 2.15 Closed Pendulum System, Nominal Coupling, Infinity/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0	0	0	-221.22	251.31	-128.55	39.840	-8.4214	1.1910	-0.00001
Mode 2	6	0.0001	0	0.0017	-24375	18763	-5621.4	817.79	-59.245	2.3445	0.00293
Mode 3	6	0.0001	0	0.0021	-30152	23485	-7143.7	1060.2	-78.540	3.0312	0.00348
Mode 4	6	0.0001	0	0.0019	-30870	23916	-7208.4	1054.5	-76.924	3.0319	0.00348
Mode 5	6	0.0001	0	0.0014	-23429	18274	-5519.8	802.94	-57.840	2.3543	0.00280
Mode 6	6	0	0	0	-524.56	600.00	-291.99	80.450	-14.066	1.5527	-0.00001

Table 2.16 Closed Pendulum System, Nominal Coupling, Infinity/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0.0001	0	0	4385.2	-3056.3	784.49	-80.080	-0.69002	1.0042
Mode 2	5	0.0000	0	0	331.80	-190.37	53.707	-10.057	-0.33837	1.0021
Mode 3	5	0.0001	0	0.0001	455.17	-233.19	55.509	-9.8151	-0.30402	1.0024
Mode 4	5	0.0001	0	0.0001	-68.091	30.839	13.938	-7.4893	-0.49468	1.0028
Mode 5	5	0.0000	0	0	156.19	-102.98	44.285	-11.064	-0.28991	1.0017
Mode 6	5	0.0003	0	0.0001	5433.5	-3690.7	911.68	-86.662	-1.35348	1.0069

Table 2.17 Closed Pendulum System, Low Coupling, Four/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0	0	0.0003	26849	-21439	6674.1	-984.72	59.776	0.47328	-0.00139
Mode 2	6	0	0	0.	1536.8	-2836.8	1445.7	-295.08	18.168	1.6827	0.00058
Mode 3	6	0	0	0.0001	-6698.2	2607.4	214.29	-204.14	21.600	1.1065	0.00114
Mode 4	6	0	0	0.0001	823.02	-3061.0	1796.7	-399.88	30.987	1.1054	0.00123
Mode 5	6	0	0	0	7203.4	-6945.5	2567.2	-432.80	24.536	1.7312	0.00066
Mode 6	6	0.0001	0.0000	0.0010	35222	-27283	8133.03	-1123.1	59.872	0.96203	-0.00233

Table 2.18 Closed Pendulum System, Low Coupling, Four/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0	0	0	-629.70	540.11	-199.22	42.627	-6.0196	0.99965
Mode 2	5	0.0018	0	0.0060	-6316.8	4222.6	-1055.9	121.13	-6.8715	0.98176
Mode 3	5	0.0009	0	0.0022	1856.0	-1133.8	258.53	-26.485	0.26648	1.0127
Mode 4	5	0.0008	0	0.0019	1378.4	-866.7	206.26	-22.085	0.05517	1.0122
Mode 5	5	0.0019	0	0.0056	-6789.6	4491.8	-1106.7	124.34	-6.9228	0.98102
Mode 6	5	0	0	0	-964.61	789.54	-273.16	53.786	-6.8944	0.99939

Table 2.19 Closed Pendulum System, Low Coupling, Infinity/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0	0	0	-3436.3	3047.5	-1136.0	235.51	-30.189	2.3400	0.00009
Mode 2	6	0.0001	0	0.0027	-17592	12140	-3192.8	412.42	-31.884	2.1353	0.00304
Mode 3	6	0.0002	0	0.0042	-24081	17087	-4648.1	618.82	-46.396	2.6446	0.00426
Mode 4	6	0.0002	0	0.0037	-18805	13392	-3688.5	508.48	-41.596	2.6694	0.00398
Mode 5	6	0.0001	0	0.0034	-96160	63465	-15952	2083.9	-205.56	19.714	0.03329
Mode 6	6	0	0	0	-62410	52728	-18426	3498.0	-399.46	26.941	0.00120

Table 2.20 Closed Pendulum System, Low Coupling, Infinity/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0	0	0	-12.517	4.128	3.7721	-2.5743	0.00181	0.99999
Mode 2	5	0	0	0	3.3708	-3.0732	1.6550	-0.70885	-0.00252	0.99998
Mode 3	5	0	0	0	14.781	-9.3684	2.9902	-0.87044	0.01358	0.99997
Mode 4	5	0	0	0	-27.812	12.968	0.44731	-1.3023	-0.00615	1.0000
Mode 5	5	0	0	0	-37.028	17.995	-0.64386	-1.1519	0.00621	1.0000
Mode 6	5	0	0	0	-10.986	-37.724	35.458	-10.525	0.03291	0.99988

Table 2.21 Closed Pendulum System, High Coupling, Four/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0	0	0	-100.56	84.716	-21.344	-2.1909	1.9238	-0.00031	0
Mode 2	6	0	0	0	-146.29	106.54	-30.280	4.0617	-0.36242	0.39654	-0.00001
Mode 3	6	0	0	0	29.657	-7.7959	-3.6002	1.6732	-0.19458	0.30542	0
Mode 4	6	0	0	0	153.14	-66.321	-0.36817	2.8595	-0.16546	0.41633	0
Mode 5	6	0	0	0	-118.45	93.600	-31.442	4.7527	-0.39542	0.53947	0
Mode 6	6	0	0	0	-795.31	455.64	-27.937	-33.734	8.1572	-0.02140	0.00004

Table 2.22 Closed Pendulum System, High Coupling, Four/Two Norm Standard Deviation Polynomial Coefficients

	Order	Error	Variance	R^2	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	5	0	0	0	-0.63402	1.7567	-2.0977	1.6702	-1.0147	1.0000
Mode 2	5	0.0020	0	0.0473	-5101.5	3352.3	-826.74	94.369	-5.1049	0.98070
Mode 3	5	0.0007	0	0.0169	2996.3	-1973.3	486.78	-54.631	2.3696	1.0115
Mode 4	5	0.0007	0	0.0112	3023.7	-1990.9	489.83	-54.320	2.1907	1.0115
Mode 5	5	0.0020	0	0.0371	-5090.5	3351.1	-827.97	94.893	-5.2221	0.98072
Mode 6	5	0	0	0	-12.258	16.498	-11.113	5.2015	-1.9361	1.0000

Table 2.23 Closed Pendulum System, High Coupling, Infinity/Two Norm Mean Polynomial Coefficients

	Order	Error	Variance	R^2	P_6	P_5	P_4	P_3	P_2	P_1	P_0
Mode 1	6	0	0	0	0.49747	0.51802	-1.7866	1.7638	-1.0190	0.39545	0
Mode 2	6	0.0001	0	0.0117	-24327	18852	-5747.4	868.65	-66.754	2.4508	0.00298
Mode 3	6	0.0002	0	0.0194	-30610	23675	-7200.3	1086.0	-83.564	3.0722	0.00380
Mode 4	6	0.0002	0	0.0075	-31369	24174	-7318.8	1096.6	-83.391	3.0743	0.00377
Mode 5	6	0.0001	0	0.0049	-24814	19226	-5844.4	876.66	-66.336	2.4401	0.00294
Mode 6	6	0	0	0	-3.9627	18.528	-19.410	10.379	-3.4799	0.75412	0

Table 2.24 Closed Pendulum System, High Coupling, Infinity/Two Norm Standard Deviation Polynomial Coefficients

Different Length Scale Behaviors. Presented below in Figures 2.18, 2.19,2.20 and 2.21 are surface plots that plot the relation between frequency of occurrence, localization and mistuning. Similar behavior is seen between the two systems, although

the circulant system appears to experience a lower degree of localization. However, the two parameters, the Infinity/Two and Four/Two norm behave quite differently.

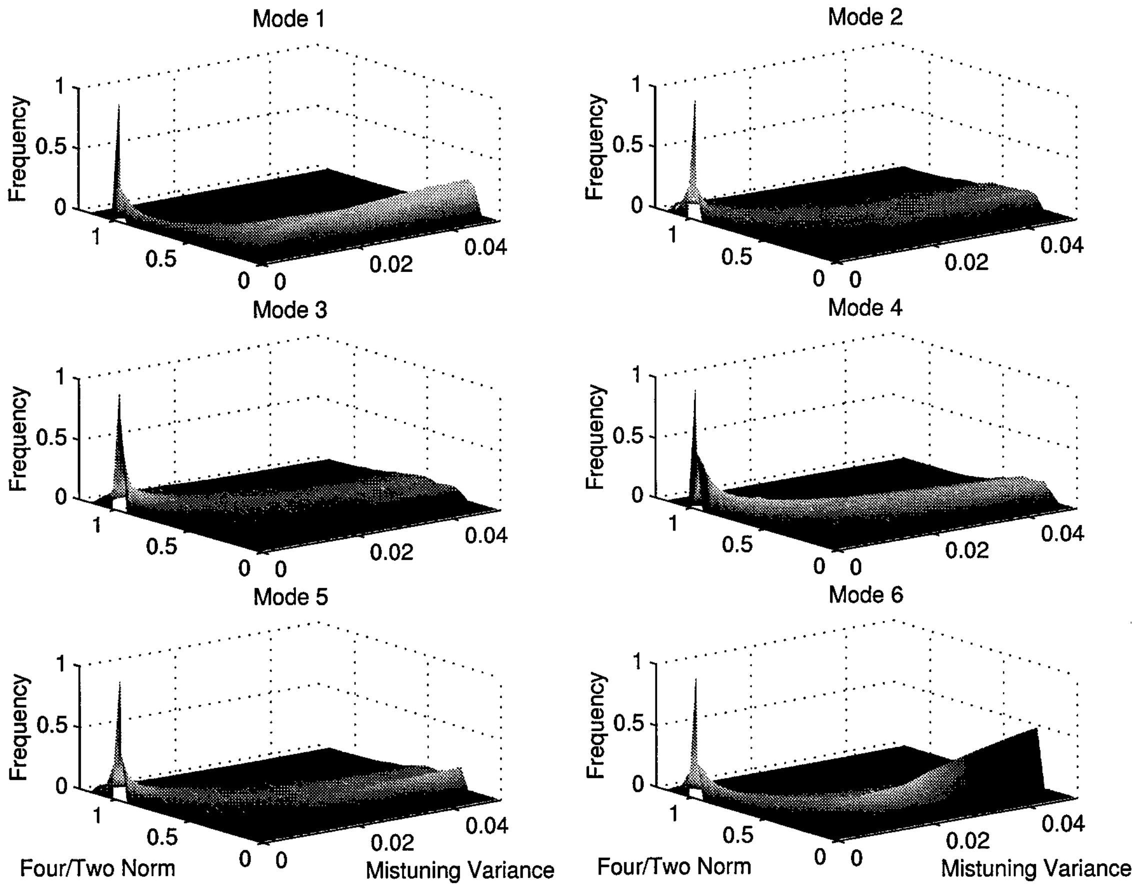


Figure 2.18 Open System, Nominal Coupling, Four/Two Norm

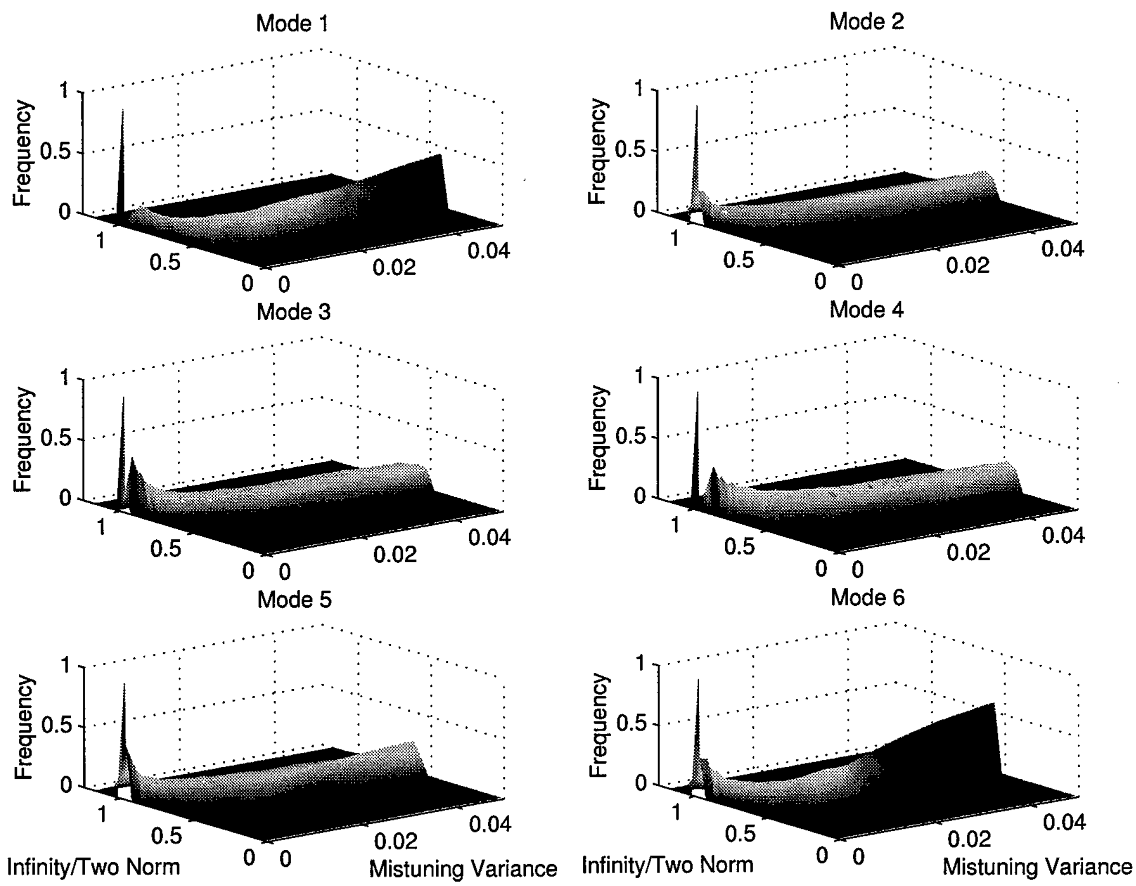


Figure 2.19 Open System, Nominal Coupling, Infinty/Two Norm

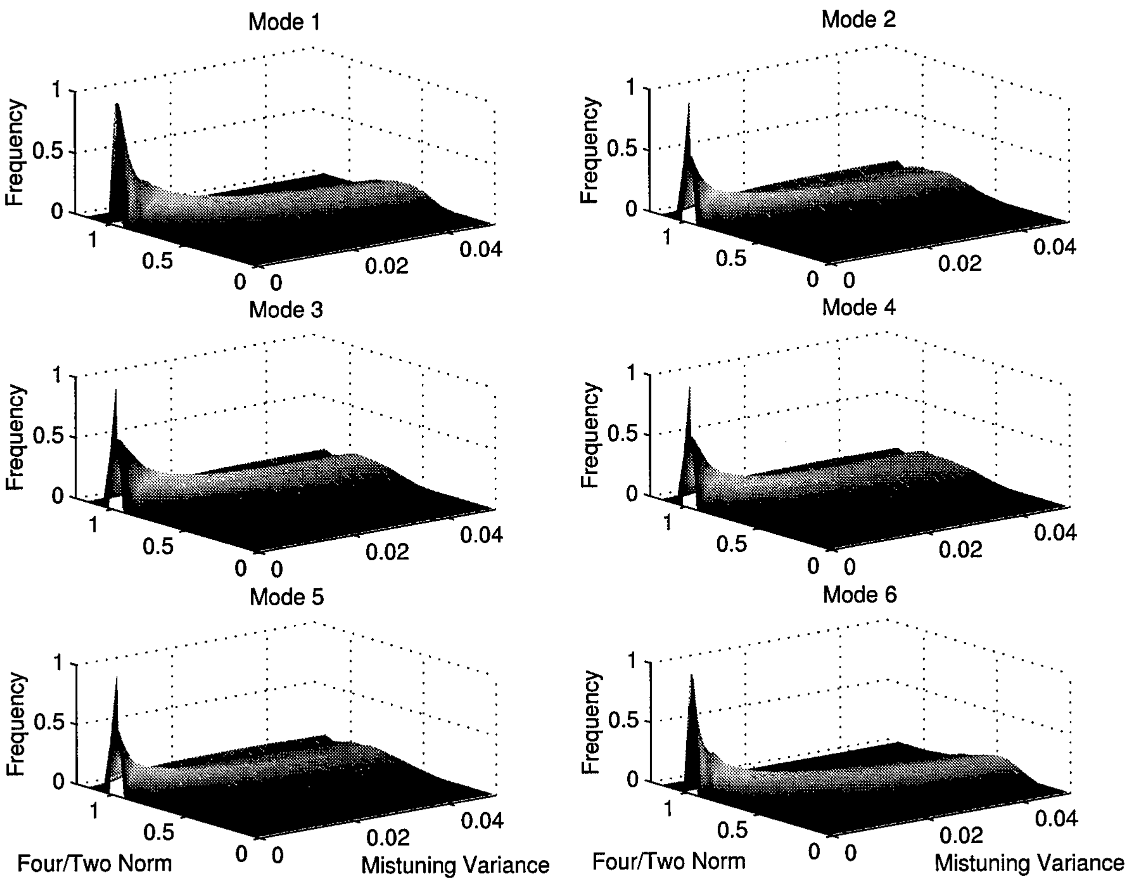


Figure 2.20 Closed System, Nominal Coupling, Four/Two Norm

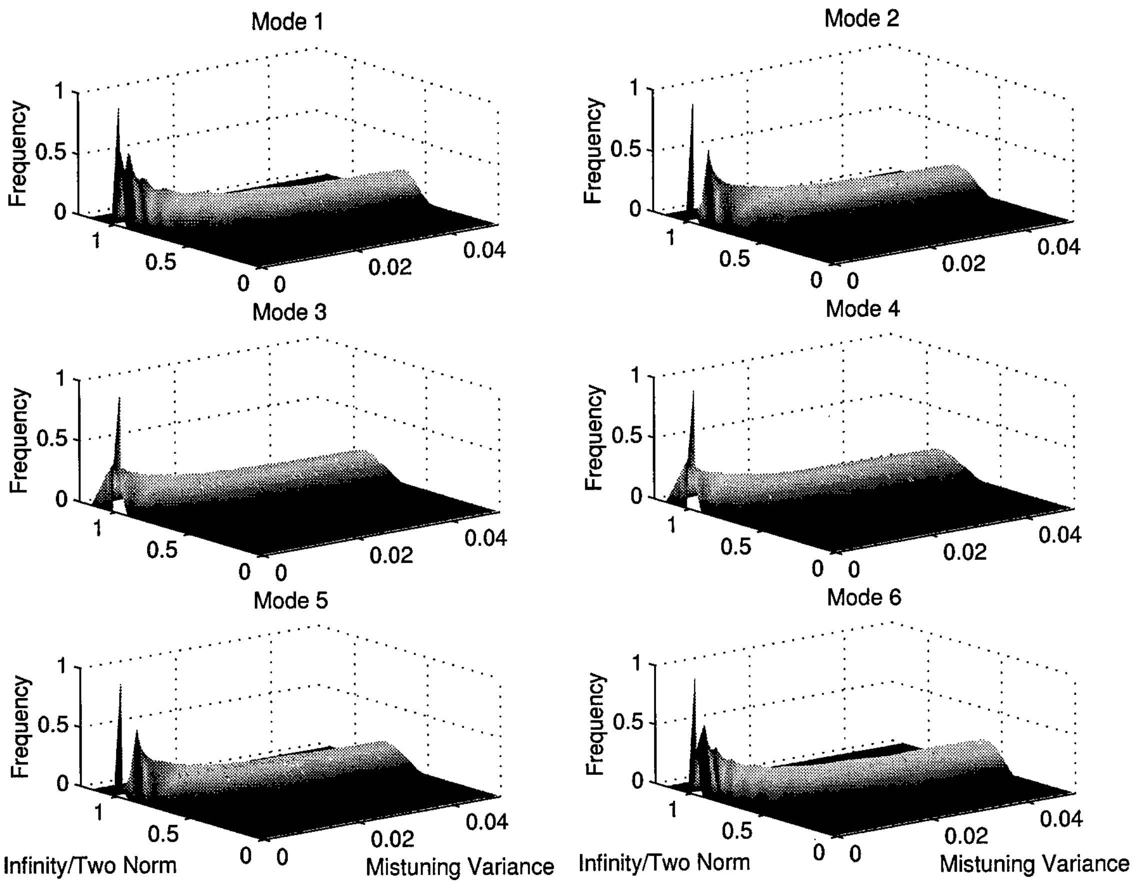


Figure 2.21 Closed System, Nominal Coupling, Infinty/Two Norm

The Infinity/Two norm has a sharper peak than the Four/Two norm, also it does not show the same degree of spread as does the Four/Two norm. It provides a 'choppier' view of the overall behavior of the system. Seen in Figure 2.22 is a comparison between the two length scales for the nominal closed system for mode 3.

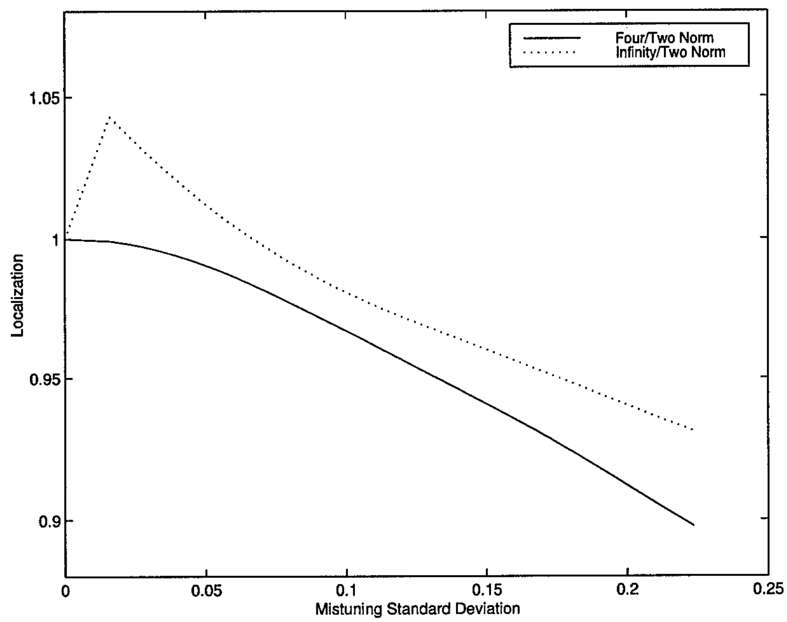


Figure 2.22   Length Scale Comparison

The Four/Two norm provides a clearer understanding of the overall trend. The Infinity/Two norm provides a less smooth view of the trend with the added bonus of reduced computation time/effort. Also, as was seen in the curve fit subsection, the four/two norm provided less error when curve fit.

The MAC scale has not been presented here because at this point it yields no apparent trends. The MAC scale yielded results that indicated high localization immediately after system mistuning commenced. The matrices of systems with slight localization apparently have poor conditioning. This is subsequently causing the Scale to indicate high localization.

Effect of Adding Quality Control. As discussed previously, a 5% filter was applied to the mistuning sets. This filter determined if any of the mistuning values of

the set deviated more than 5% from the nominal mass of 1. The behavior of both systems, closed and open, prior to and after the application of the filter are compared in this section.

Shown in Figures 2.23 and 2.24 are the responses of both of the nominal systems to the addition of the quality control filter. As can be seen the 5% filter had a significant effect on the system for medium to high levels of mass mistuning.

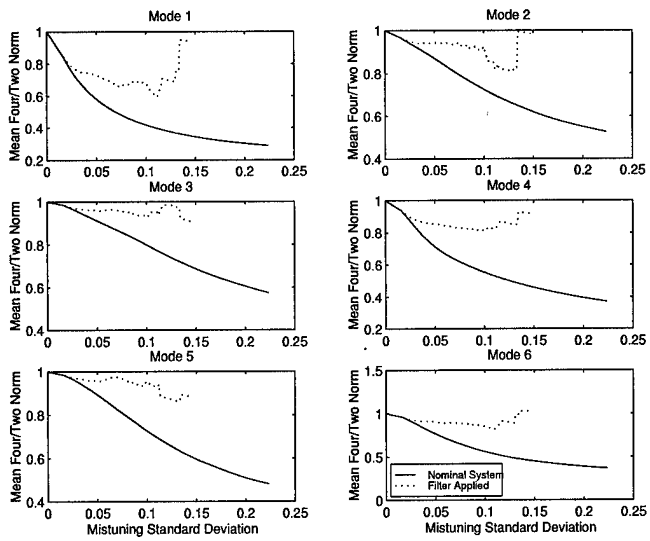


Figure 2.23 Nominal Open Ended System With Quality Control Filter Applied

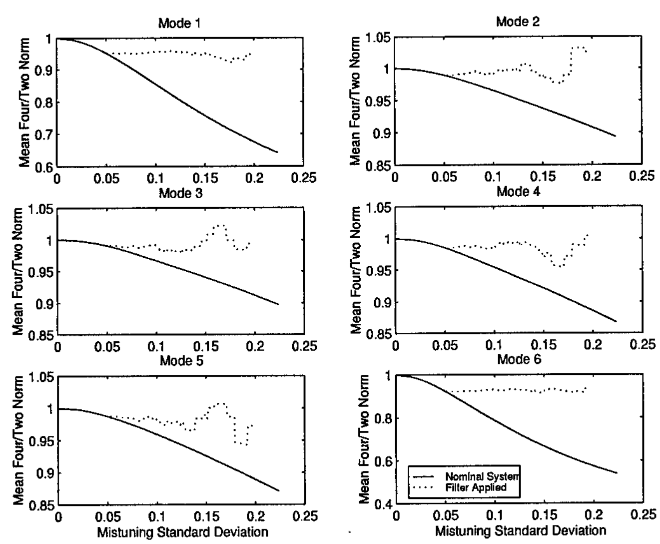


Figure 2.24 Nominal Closed Ended System With Quality Control Filter Applied

The reduction in curve smoothness is due to a loss of data from the filter. For the higher levels of mistuning, the filter eliminates all of the systems. This results in a termination of system observation at a mistuning standard deviation of approximately 0.2 and 0.15 for the closed and open systems respectively. Although the curve for the system results with quality control filters in place is not as optically pleasing, the mean localization it indicates is a marked improvement over the non-filtered systems for higher mistuning levels.

In comparing the behavior of the open and closed systems, it can be seen that the filtered results for the open system deviates from the non-filtered first. The higher degree of separation between the filtered and non-filtered curves, for open system, is probably due to the higher degree of localization it experiences relative to the closed system.

Comparison of the Two Systems. The most significant difference that existed between the two systems was the additional coupling present in the circulant system. This additional coupling reduced the circulant system's response to mistuning relative to the response of the open ended system.

Additionally, the modes affected by localization were different for the two systems. Modes 1 and 4 (in that order) were the most susceptible to localization in the open ended system; whereas the end modes, modes 6 and 1 were the most susceptible in the circulant system.

Summary

The effects of system mistuning and coupling on mode localization have been investigated in this chapter. The dependence of localization on system mistuning level and coupling were found. For both simple systems, localization was found to decrease as inter-component coupling increased. The coupling was also found to have effects on the trends the system localization standard deviation followed. Additionally, as expected, system localization was found to increase with increasing mistuning level. Curve fits were accomplished for the localization to mistuning relationship for all levels of coupling for both systems.

In the following chapter similar analysis will be conducted on an actual space-array-like test structure. The system will be tested multiple times at three mistuning levels for three coupling levels. Similar trends to those seen here are anticipated.

III. Experimental Overview

The Experimental work that was undertaken has two purposes. The first purpose is to show, statistically, how mode localization varies as both the level of system disorder and coupling are varied. The second purpose is to explore the effects of increased coupling via piezoceramics on the behavior of a localized system.

Both of these purposes were achieved by the methodology presented in the following sections. Discussion of the experimental hardware, procedure, analysis and preliminary results is presented in this Chapter. Further discussion and comparison to the numerical results of Chapter 2 can be found in Chapter 4.

Experiment Equipment

A brief overview of the equipment utilized is first presented, focusing on how the equipment works in concert to generate and acquire experimental data. More in depth discussion of individual pieces of equipment can be found in the following subsections.

A generic block diagram view of the system is depicted in Figure 3.1. As shown, excitation signals are generated and output data is received by a Personal Computer (PC), a Hewlett Packard (HP) VXI Plug and Play system is the interface between the remainder of the experimental system and the PC. After undergoing amplification, the electronic signal is converted to a physical excitation by means of (for the most part) piezoceramic actuators that are bonded to the test structure. The test structure undergoes some form of physical response, measured via accelerometers placed on the structure. The accelerometers output a low voltage that correlates to the acceleration of the structure at their mounting position. This voltage is then amplified and sent back to the computer by way of the HP.

Data Acquisition. The data acquisition portion of the experimental equipment is composed of both hardware and software. To logically discuss the data acquisition components, the following discussion will flow from the user assigning an excitation with

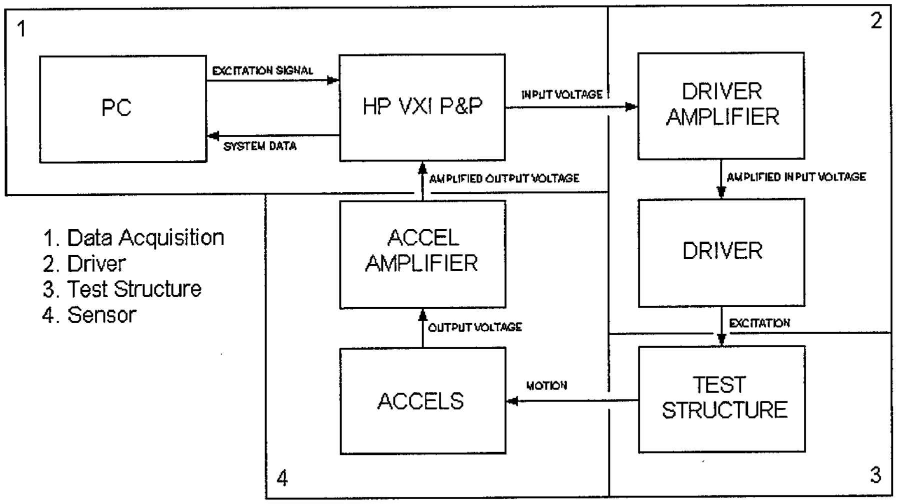


Figure 3.1 Experiment Set Up Block Diagram

the PC based user interface through the various hardware and software components back to the user receiving the desired (or disappointing) data, as shown in Figure 3.2.

User interface to the system is accomplished through a graphical user interface program named Datascope. Datascope, written in MATLAB®, is an in-house data acquisition and analysis package. The data acquisition portion of Datascope is derived from demonstration files downloaded from the Hewlett Packard web site. The development of the Datascope interface program is partly related to this thesis. Portions of it required for the accomplishment of this thesis were developed as needed. These portions include its accelerometer calibration, chirp generation and current analysis capabilities. These capabilities will be discussed, where pertinent, in later portions of this document.

The software interface between Datascope and the data acquisition hardware is a Dynamic Linked Library (DLL) driver acquired from the HP web site. This DLL allows the Datascope interface to initiate instrument calls to the HP hardware [17]. The Datascope and DLL software/code resides on the hard drive of the PC, the physical link between the PC and the HP equipment is accomplished with an Adaptec®AHA-8940 1394-to-PCI Host Adapter. This is essentially a card installed in the PCs backplane [18].

The Adaptec® card carries the excitation signal along with various commands from the PC to the HP E8491 PC Link to VXI Interconnect. Drivers for the HP E8491 and the

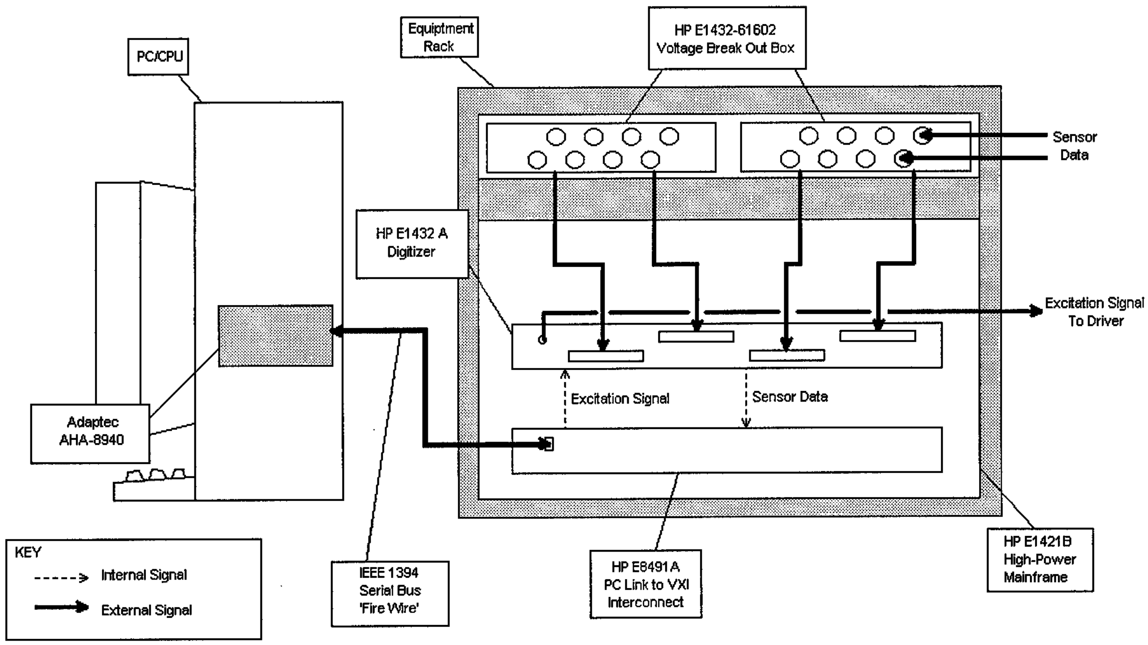


Figure 3.2 Data Acquisition Up Block Diagram

Adaptec® reside on the hard drive of the PC. The HP E8491 resides in the 0 slot of the HP E1421B Mainframe. The HP E1421 Mainframe provides a plug and play interface for the various cards that are placed in its slots. An HP E1432A Digitizer resides in slot 2 of the mainframe. The various commands and signals travel from the E8491 through the mainframe to the HP E14323A. The digitizer processes the information from the PC and sends the excitation signal to the driver amplifier.

Once the signal has been sent, the HP E1432A digitizer is triggered to take data (the setup utilized throughout the experimentation triggered the sensor input off of the excitation source). Sensor data travels from the sensor amplifier to an HP E1432-61600 Break Out Box. From there the data is sent to the digitizer back through the remaining HP hardware to the PC, where the user can view the incoming sensor data.

Driver Description. The structure was driven/actuated with six Active Controls Experts (ACX) model QP21B Quickpack bimorph actuators. A picture of the actuators on the structure is shown in Figure 3.3. The actuators consist of two electroni-

cally independent piezoceramic elements stacked on top of one another and packaged in a polyimide skin[2].

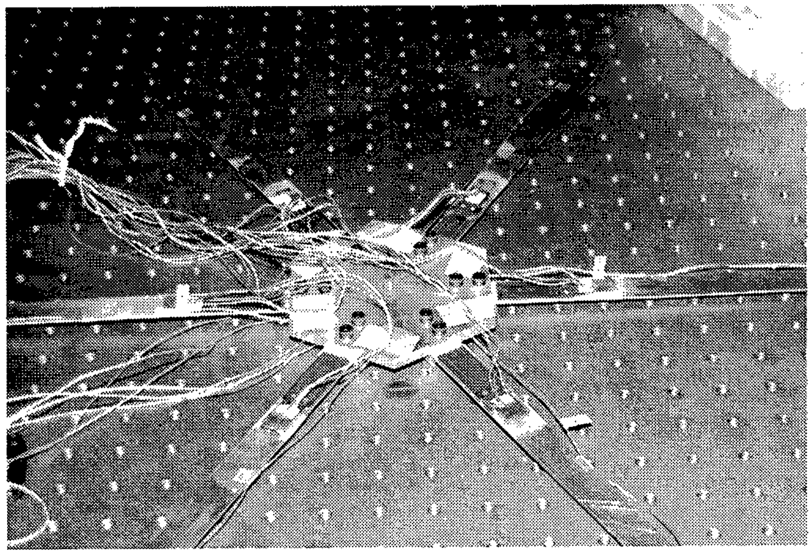


Figure 3.3 PZT Bonded to Antenna Array

To achieve actuation, the elements require a high voltage (± 100V)/low current supply [1]. To provide this supply, a Quickpack power amplifier (ACX Model EL 1224) was placed in line between the excitation signal supply and the actuators. The model's maximum voltage and current settings were set at 100V and 50mA for all of the testing conducted. A schematic of the Quickpack is shown in Figure 3.4.

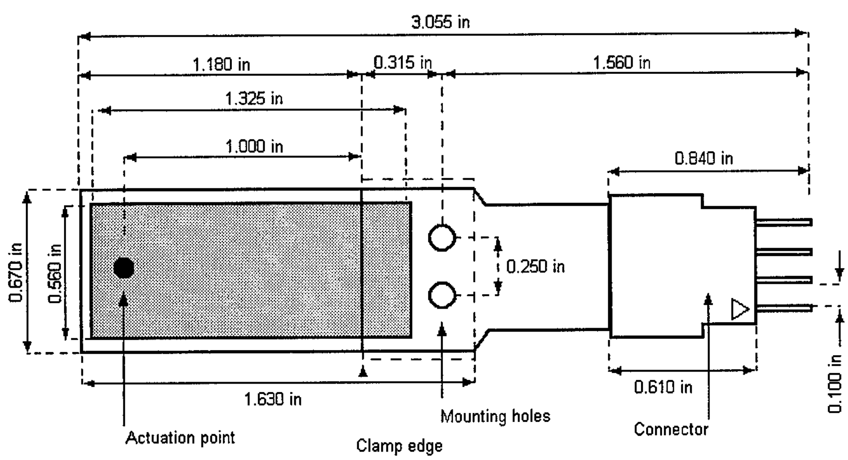


Figure 3.4 PZT Pack Schematic [1]

Due to the test method, convenient switching between which Quickpack excited the structure was required. To accomplish this the board of BNC connectors shown in Figure 3.5 was constructed. The board allows the experimenter to select the element (inner or outer) and PZT pair to be driven. The positive and negative leads from the back of the BNC connectors are connected to a breadboard. The supply wires for the PZT pairs are appropriately wired to the board so that the correct elements and pairs are actuated.

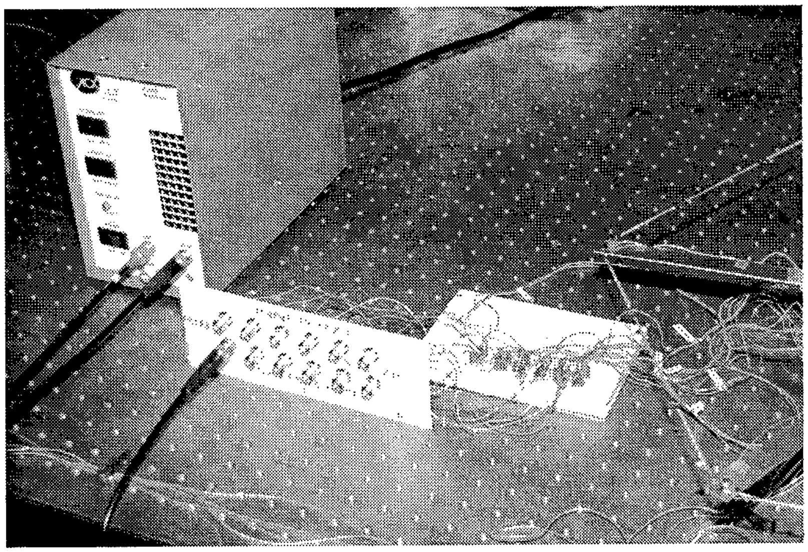


Figure 3.5 BNC Supply Board

To reduce the weight of the piezoceramic actuators, the connector portion of the pack was removed. Wire leads were soldered to the exposed leads. The soldered leads were then shrink wrapped to prevent damage.

The actuators were bonded to the base of the antenna ribs with M-bond 2000. The manufacturer supplied adhesive was used on a trial basis and found to have undesirable characteristics. The manufacturers application technique required a 24 hour cure with the constant application of a vacuum to the region where the adhesive was curing. Even after following the instructions, the adhesive remained tacky for several days after the curing process. The M-Bond procedure required only a thorough cleaning of the bonding surface and slight pressure on the bond while it cured.

To prevent banging between the rib and the shrink wrapped portion of the PZT, that portion was taped to the rib as seen in Figure 3.3.

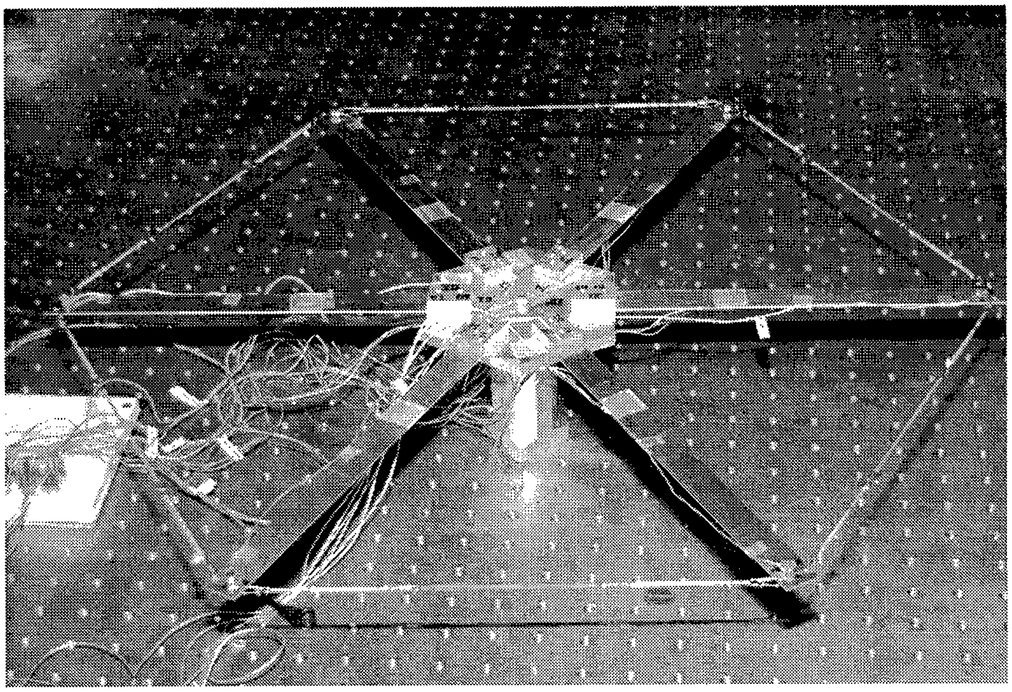


Figure 3.6 Assembled Test Array

Test Array Description. The test specimen utilized for this experiment is designed to be a space-like structure; more specifically it is similar to an antenna array. A picture of the test array is shown in Figure 3.6. The array structure is composed of (excluding bolts) a hexagonal base plate, six nearly identical cantilever beams, six cover plates and one stand. Each of these components is made of aluminum. Dimensions/drawings of each component (excluding the stand) can be seen in Figures 3.7, 3.8 and 3.9.

The full array, shown in Figure 3.6, was constructed by clamping each of the cantilever beams to the hexagonal base plate. Clamping was accomplished through use of two bolts and one cover plate for each cantilever beam. The beam was placed between the base plate and cover plate and bolts were run through holes in the base plate and cantilever beam to threaded holes in the cover plate. The bolts were tightened to prevent any slippage or rattling of the cantilever beams. After the beams were attached to the hexagonal base plate, the base plate was then bolted through its' center hole to a solid aluminum stand. The array stand was bolted to a pneumatically isolated table. The isolation provided a reduction in noise from ground sources.

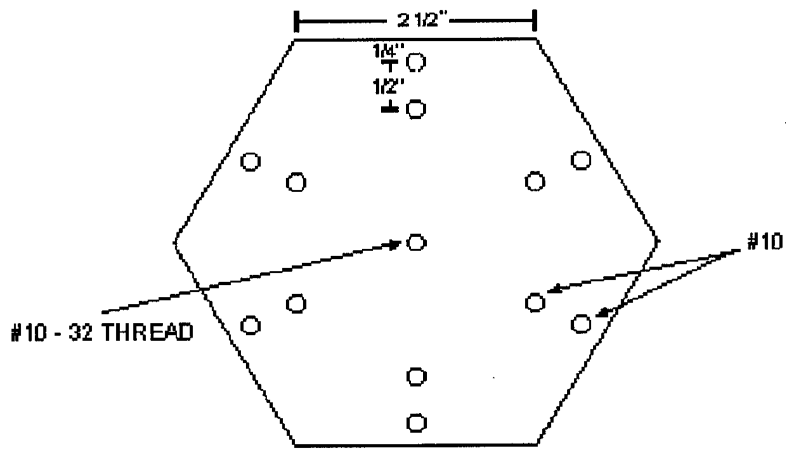


Figure 3.7   Hexagonal Base Plate

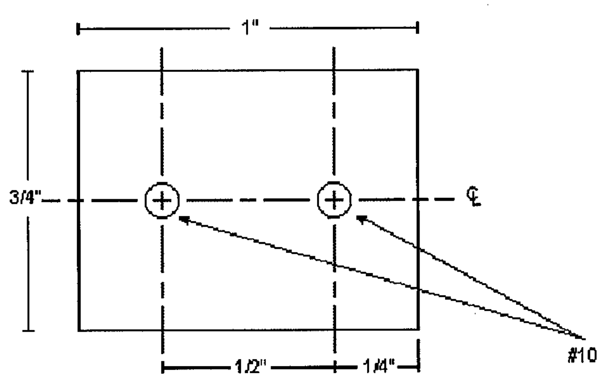


Figure 3.8   Cover Plate

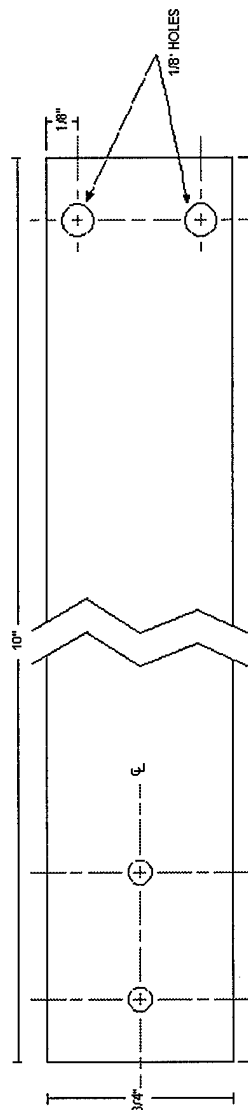


Figure 3.9 Cantilever Beam

Coupling between the cantilever beams was accomplished with rubber bands. A set of these is shown on the array in Figure 3.6. Each coupling device is constructed with two cloth loops, a rubber band and four metal wire snaps. A total of four sets (each set containing six coupling devices) were constructed, each providing a different level of coupling.

Sensor Description. The response of the structure to excitation was measured with six accelerometers. An accelerometer was located 3/8ths of an inch from the tip of each of the cantilever beams. The accelerometers utilized were ENDEVCO® model 2250A-10.

The accelerometers had a nominal sensitivity of 10 mV/g and a range of ±500g. For the majority of the experiments completed, the frequencies measured ranged between 8 and 20 Hz; the lower end of the usable range of the accelerometers. Low deviation between the measured and actual frequency magnitude exists in this region; however, phase error on the order of five percent is present [10]. Measurements were taken at room temperature. For the range from 60 to 80°F, the accelerometers display a magnitude error of approximately one percent [10].

The power supply/amplifier for the accelerometers was a Kistler® model 5124A Piezotron Coupler. Each accelerometer's signal went from this amplifier to the HP break out boxes.

One of the drivers in the selection of the ENDEVCO® accelerometers was their availability - they were already owned by AFIT. Beyond the cost benefits of these accelerometers, they also had acceptable performance in the frequency range considered and low mass (0.4 grams).

The accelerometers were attached to the structure with a thin layer of modal wax. This attachment method is valid for frequencies between 0 and 2000 Hz[4]. The frequencies considered for this experiment fall well within that region.

To reduce noise, the wires for the accelerometers were taped in two places along the individual antenna ribs (the cantilever beams) and once on the base hexagonal plate as

seen in Figure 3.6. This taping prevented excessive flapping of the accelerometer leads when the array was excited.

Experimental Procedure

The experimental procedure has three major portions. First, the individual components of the system were characterized. Characterization was completed to see what deviation exists in the component properties. Deviation in components causes localization in the whole system.

The second is analysis of the bare system as a whole. The bare system considered is the whole system with PZT material attached. The bare system was tested with varying levels of inter-rib coupling. Study of the bare system provides a measure of the mode localization occurring in the system prior to intentional mistuning.

The third and final portion of experimentation involved intentional mass mistuning of the system for various levels of inter-rib coupling. Additionally, for both the bare and mistuned portions of the study, the effects of PZT coupling on the behavior of the system was analyzed. Shown below is an outline of the procedure to be followed. The following sections will discuss how these portions of the experiment were conducted and what results they yielded.

1. Calibrate accelerometers to be utilized for the test
2. Determine individual rib properties (with and without PZT)
    (a) Measure the mass of the individual ribs
    (b) Measure the dimension of the individual ribs and cover plates
    (c) Determine individual rib natural frequencies and damping for first cantilever mode
    (d) Determine rib stiffness
3. Determine the properties of the PZT Quickpacks
4. Determine the mistuning mass sets to be utilized

5. Determine the stiffness and damping of the rubber bands utilized for inter-rib coupling
6. Determine the whole system's modal characteristics with various levels of inter rib coupling (none, orange, yellow and green)
7. Determine the whole system's modal characteristics with various levels of inter rib coupling with PZT coupling
8. For each of the coupling levels, determine how the system behaves with multiple mistuning mass sets

Results

Included in the following subsections are first the results of the system characterization, second, the mistuning results and third, the results of adding PZT coupling to the system.

System Characterization. Prior to conducting the experiments for this study initial system characterization was conducted. Detailed herein are the some of the procedures and the results of these experiments.

Accelerometer Calibration. Comparison calibration was utilized to determine the sensitivities of the accelerometers used in this experiment. The equipment setup can be seen in Figure 3.10. The shaker utilized was an MB Dynamics Model Cal 50, fifty pound shaker. Excitation signals from the HP E1432A were amplified by an MB Dynamics model SS530 amplifier before they went to the shaker. The standard accelerometer and its power supply are the components of a PCB Piezotronics Model 394A10 vibration calibration system with a sensitivity of 100mV/g. The test accelerometer was mounted on the standard accelerometer with modal wax.

A random signal with a range of $\pm 8V$ and bandwidth of 1280 Hz was utilized as an input to the shaker. The digitized knob on the amplifier was set to one click before its middle setting. The channel range for the standard accelerometer was set at $\pm 1V$, and the channel range for the ENDEVCO® accelerometer was set at $\pm 0.1V$. Data for both the

true and test accelerometer were sampled at a rate of 2560 Hz. Eight 8192 point blocks of data were taken for each accelerometer.

The time signals from both of the accelerometers was then analyzed to determine the coherence between the two accelerometers and the magnitude and phase of the frequency response between them. An H_v algorithm with data overlap and hanning windows on the time data was utilized to determine the FRF. Due to the fact that the accelerometers were mounted one on top of the other, the poor phase identification abilities of this algorithm were not a factor. However, its ability to improve magnitude identification was useful. This algorithm was incorporated in the Datascope program as an analysis tool. The code utilized in Datascope is shown in Appendix A.

A fifty percent overlap was utilized for the analysis of the accelerometer sensitivities. The frequency responses of 64 blocks of data, at a block size of 1024, were averaged to determine the sensitivity of the accelerometers. The RMS value of the sensitivities of the ENDEVCO® accelerometers utilized throughout the experiment are shown below in Table 3.1. The sensitivities were nearly flat in the frequency range of interest for the modal experiments conducted. There are more than six values shown due to spare accelerometers that were utilized when primary accelerometers malfunctioned.

Serial Number	Sensitivity (mV/g)
CB96	9.94
CD61	9.99
CD33	10.05
CD47	10.36
CD42	9.24
CP38	10.06
CB77	9.88
CD05	10.10
CB48	9.59

Table 3.1 ENDEVCO® Accelerometer Sensitivities

Individual Rib and Cover Plate Dimensions and Mass. The individual rib and cover plate dimensions were measured with a Fowler Precision Dial Caliper (model MH 18600). The individual dimensions were measured multiple times and then averaged to attain a value for the specific dimension. Some difficulty existed in measuring the length of the individual ribs. The individual ribs are longer than the maximum range

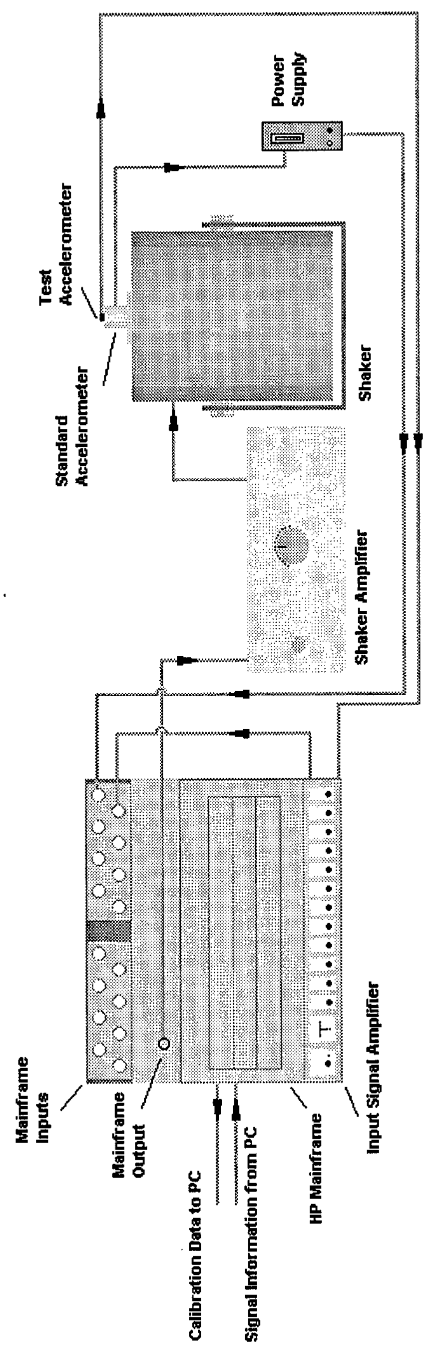


Figure 3.10 Calibration Equipment Setup

of the caliper that was used. To overcome this, a marking was made near the middle of each rib. The distance from each rib end to this midpoint was then measured and the two measurements were summed to find the value for the rib's length. The rib and cover plate dimensions can be seen in Tables 3.2 and 3.3 respectively. Figures 3.11 and 3.12 show a representative rib and cover plate with the dimensions measured. It should be noted that the ribs are numbered two through seven instead of one through six. Rib one was used as a test case. Ribs two through seven were utilized for the test array.

The mass of each rib was determined with a Denver Instrument Company Model XL-300 scale. As with the dimensions, multiple measurements of the individual ribs were made and then averaged to determine the rib mass. The masses of the individual ribs can be seen in Table 3.2.

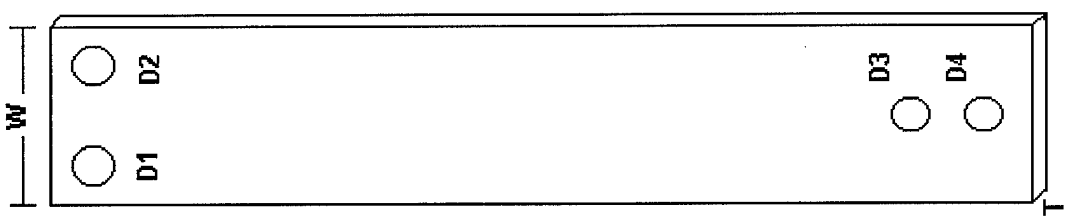


Figure 3.11 Antenna Rib

Rib Number	Width (in)	Thickness (in)	Length (in)	Mass (g)	Dia. 1 (in)	Dia. 2 (in)	Dia. 3 (in)	Dia. 4 (in)
2	0.751	0.040	9.999	12.590	0.123	0.123	0.190	0.190
3	0.751	0.041	10.00	12.573	0.122	0.122	0.189	0.189
4	0.751	0.041	10.00	12.600	0.124	0.123	0.190	0.190
5	0.752	0.041	10.00	12.594	0.123	0.123	0.190	0.190
6	0.752	0.041	10.00	12.607	0.123	0.123	0.190	0.190
7	0.751	0.041	10.00	12.614	0.123	0.123	0.190	0.190
Mean	0.751	0.041	10.00	12.600	0.123	0.123	0.190	0.190
Std. Dev. (%)	0.0627	0.9127	0.0037	0.1040	0.4694	0.3034	0.1963	0.1963

Table 3.2 Rib Dimensions in Inches and Mass in Grams

For the base array system PZT is bonded to each rib, modifying its mass, stiffness and damping. The mass of each rib with PZT added to it is shown in Table 3.4.

The standard deviation for all of these values is well within one percent. This low deviation is desired, as it indicates these parameters should not be significant contributions to system disorder, which could lead to localization. However, even this low mistuning level may result in mode localization of the system.

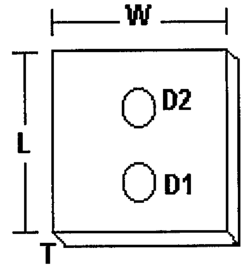


Figure 3.12 Cover Plate

Plate Number	Width (in)	Thickness (in)	Length (in)	Diameter 1 (in)	Diameter 2 (in)
2	0.753	0.251	1.005	0.155	0.156
3	0.753	0.251	1.003	0.156	0.156
4	0.753	0.252	1.003	0.156	0.156
5	0.753	0.253	1.004	0.156	0.156
6	0.752	0.249	1.003	0.156	0.156
7	0.753	0.252	1.004	0.156	0.157
Mean	0.7528	0.2513	1.0037	0.1558	0.1562
Standard Deviation (%)	0.0495	0.4962	0.0743	0.2392	0.2386

Table 3.3 Cover Plate Dimensions

Rib Number	Mass (g)
2	15.604
3	15.730
4	15.612
5	15.604
6	15.585
7	15.747
Mean	15.647
Standard Deviation (%)	0.4182

Table 3.4 Rib Masses With PZT

Individual Rib Natural Frequencies and Damping. The fundamental natural frequency and damping of each rib, with and without PZT, has been determined through impact testing. The properties of the individual ribs were determined to find the errors that exist in the system prior to intentional mistuning. The properties of the bare ribs (prior to bonding with PZT) are next discussed.

Marks were made at each inch along the centerline of each rib. The ribs, while mounted on the hexagonal base, were then impacted at a point four inches from the tip of the rib. A modal hammer with an aluminum tip was utilized for the impacts. It should

be noted that two impact locations were investigated, one two inches from the tip and the other four. The one four inches from the tip provided the most observable decays.

Time data was obtained at a sample rate of 256 Hz. Eight blocks of 2048 data points, were taken for each decay. Once obtained, the time data was analyzed with an Eigensystem Realization Algorithm (ERA)[11][13]. This analysis method provides estimates of natural frequency and damping from decay data. Analysis was performed on multiple portions of the oscillation decay. The MATLAB m-files utilized for the ERA analysis conducted were written by Joseph Hollkamp of Air Force Research Laboratory (AFRL).

A matrix called a Hankel matrix is formed from the decay data. The number of rows affects how much data is analyzed. The number of columns affects how many modes can be determined. At minimum, the number of columns is twice that of the number of modes to be determined [11]. More columns should be utilized when data is noisy. Hollkamp and Gordon recommended ten columns per mode for moderately noisy data [11]. As for the number of rows, the more rows utilized the better the estimate should become. ERA is essentially a least squares method [11].

The start of the decay data analyzed was where the signal from the accelerometer remained in a $\pm 0.1mV$ envelope. Starting at this point allowed a standardization of the data analyzed, since the impacts from the modal hammer were not identical. The Hankel matrix size utilized was 150x30. The value of 30 was selected because, from preliminary impacts, it appeared that three modes were present in the frequency range analyzed, one around 17 Hz, one around 40 Hz and one around 90 Hz. Ten columns per mode, for noisy data, times three, for three anticipated modes, yielded 30. As for the value of 150 columns, it was found that that value yielded consistent frequency and damping values.

Once the Hankel matrix is formed, the algorithm factorizes it with singular value decomposition [11]. The number of singular values retained affected how much of the data was retained. Keeping a large number of singular values may result in noise in the parameters obtained. The estimated parameters of frequency and damping were plotted versus singular values, and the singular value cutoff was selected where consistency existed in the estimated values. For the analysis of the beam decays, the singular values were

typically about 10. The values for frequency and damping for the individual ribs are shown in Table 3.5. The standard deviation of the frequency is less than 1%. The damping has a considerably higher standard deviation, approximately 3.5%. It was difficult to obtain consistent damping values in the analysis, which leads to a suspicion that the increased damping deviation is an artifact of the analysis.

Rib	Frequency (Hz)	Damping (% of Critical)
2	14.60	0.4565
3	14.41	0.4446
4	14.58	0.4618
5	14.45	0.4678
6	14.49	0.4191
7	14.63	0.4571
Mean	14.53	0.4511
Standard Deviation (%)	0.5592	3.534

Table 3.5 Bare Rib Modal Characteristics

Individual Rib Stiffness. The individual rib bending stiffness was determined with frequency, mass, and dimension information on each rib. They were derived with the following equations obtained from [21] for the first cantilever bending mode of a thin beam. The stiffness values, the equivalent stiffness for the first bending mode, for each rib are shown in Table 3.6.

$$k = \frac{3EI}{l^3} \tag{3.1}$$

$$\omega_1 = 3.52\sqrt{\frac{EI}{ml^4}} \tag{3.2}$$

Where m is mass per unit length.

$$E = \frac{ml^4}{I}\left(\frac{\omega_1}{3.52}\right)^2 \tag{3.3}$$

$$k = 3ml\left(\frac{\omega_1}{3.52}\right)^2 \tag{3.4}$$

Rib	Stiffness (N/m)
2	24.39
3	24.02
4	24.62
5	24.16
6	24.37
7	24.89
Mean	24.41
Standard Deviation (%)	1.166

Table 3.6 Individual Rib Stiffness Values

PZT Quickpack Properties and Effects on Rib Characteristics. Two concerns existed with the PZT Quickpacks. First, which PZT pair should be used to drive and which should be used to couple. Second, what are the effects of the PZT on the rib characteristics, and what are the effects of the wiring boundary conditions on the PZT.

It is desirable to have the most output to voltage input for the coupling set of PZT. To find which pair had the highest output to input, each rib was excited with a random signal. The rms of the output acceleration at the rib tip to the input voltage was then determined. The random signal utilized had a range of 8 Volts. Data was sampled from the accelerometers and voltage source at a rate of 640 Hz. Eight blocks of 4096 data points were taken. The range on the accelerometer channel was set at 0.2 Volts, and the range for the input voltage channel was set at 8 Volts.

The system response data was analyzed with the H_v algorithm described in the calibration section. 16 averages were utilized with a data block size of 2048 and a fifty percent overlap. The input rms values for each test were measured to be 1.53 Volts. The rms values for the output acceleration to input voltage are shown in Table 3.7. Note, "inner" denotes the pair closest to the rib and "outer" is the pair furthest away. The table clearly indicates that the inner pair generates a larger response.

Due to these results, the inner pair was left for coupling and the outer pair was used for driving the structure. This result was somewhat counterintuitive. It was initially suspected that the outer pair would have a higher output to input due to its increased

Rib	Inner Pair RMS (g/V)	Outer Pair RMS (g/V)
2	0.0958	0.0538
3	0.0988	0.0623
4	0.0854	0.0458
5	0.0958	0.0478
6	0.0946	0.0543
7	0.0941	0.0577

Table 3.7 PZT Pair Driving Performance

moment arm. It is unknown why this was not the case; it may be due to slip in the Quickpack material.

During this testing, it was found that ribs 2 and 5 had less than satisfactory response. It was determined that rib 2's bond had been sheared during preliminary impact testing and that rib 5's bond had not cured correctly. This brought up the potential of losing the quickpacks adhered to the beams, a costly endeavor. It was found that the PZT quickpacks could be easily removed from the rib surface with a straight razor. The Quickpack and rib surfaces were cleaned and bonded once again. The new bonds worked as well as those on the other ribs.

Addition of the PZT to the base of the ribs affected the rib's behavior. Impacts for various electronic boundary conditions were considered for the PZT. This was done to see what effects these conditions had on the measured modal characteristics of the beam. Of primary interest were two impact tests, the first with both leads open and the second with the inner leads open and the outer leads receiving a zeroed out signal from the source. Impacts with both PZT leads open simulated the typical condition for the five non-driven ribs during the full array testing. Impacts with inner lead open and the outer lead attached to a zeroed out source simulated the driver ribs during a decay from a chirp.

Both sets of impact tests had the same setup. The sampling frequency was an excessive 6400 Hz (decimation is easier than recreation). Eight blocks of 4096 points were taken. Excitation was accomplished by impacting a centerline point 4 inches from the rib tip with an aluminum tipped modal hammer.

As for analysis, a 40x800 Hankel matrix was utilized to be on the safe side. It turned out that decimating the data by 10 yielded the best results. That is to say, mode splitting

was observed in the data at that level of decimation. Typically good modal parameter estimation is achieved when the singular value cutoff is selected just prior to the split. The singular value cutoffs for both sets ranged between 6 and 15. The results of the impact tests are shown in Tables 3.8 and 3.9.

Rib	Frequency (Hz)	Damping (%)
2	17.43	0.52
3	17.36	0.63
4	17.86	0.71
5	17.18	0.87
6	17.46	0.66
7	17.53	0.73
Mean	17.47	0.69
Standard Deviation (%)	1.1624	15.27

Table 3.8 Rib Characteristics With Both PZT Pairs Open

Rib	Frequency (Hz)	Damping (%)
2	17.50	0.70
3	17.33	0.65
4	17.75	0.79
5	17.19	0.83
6	17.46	0.55
7	17.49	0.71
Mean	17.45	0.4511
Standard Deviation (%)	0.9827	13.25

Table 3.9 Rib Characteristics With The Inner PZT Pair Open and The Outer Connected to A Zeroed Source

Although there is a difference between the two conditions, there is no specific pattern (i.e. all damping and frequencies increased, etc.). Overall there was a mean decrease of 0.02 Hz in the rib natural frequencies and a mean increase of 0.03 % in the dampings from the open/open to the open/zeroed condition.

Addition of PZT definitely changed the frequency and damping properties of the bare ribs. Addition of the PZT increased the natural frequency and damping for all of the ribs. Unfortunately, it also increased the mistuning in the system. Overall, there was a mean increase of 2.94 Hz in the rib natural frequencies and a mean increase of 0.24 % in

the damping. These changes in the bare ribs are in comparison to the open/open boundary conditions.

Coupling Device Stiffness. A dynamic method was utilized in determining the stiffness of the rubber bands that coupled the rib tips. The problem faced in measuring this quantity is the non-linearity of the rubber bands. For the test method, the entire loop set was measured. This was done to account for any stiffness variations due to the other pieces that are utilized in coupling the ribs.

The oscillation frequency of the loop set was determined to indirectly find its stiffness. Given the loading mass required to elongate the loop set to its length when on the array, one can use the relations shown in Equations 3.5, 3.6 and 3.7 to determine the loop set stiffness.

$$\omega = \sqrt{\frac{k}{m}} \tag{3.5}$$

$$\omega = 2\pi f \tag{3.6}$$

$$k = m(2\pi f)^2 \tag{3.7}$$

The dynamic testing was accomplished using the apparati shown in Figures 3.13 and 3.14. The first and second apparati were utilized for high and low mass loading respectively. For both apparati, sufficient loading mass was added to achieve the same elongation experienced when the loop sets are on the array. This was done to prevent variations between the measured stiffness and the true stiffness due to non-linearity from elongation difference. The non linearity of the loop causes short and long elongations to yield low and high oscillation frequencies respectively.

When the test apparatus was fully configured the mass was displaced by a small amount, released and allowed to oscillate. The extension experienced throughout the

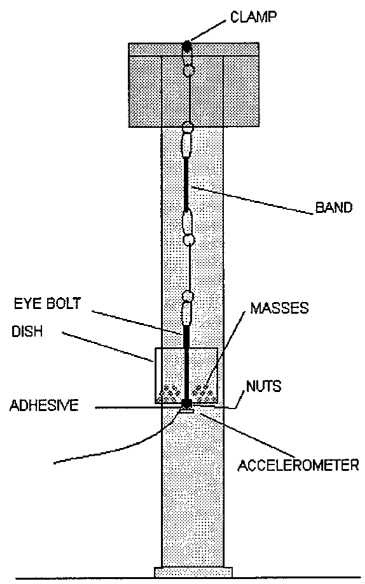


Figure 3.13 Loop Stiffness Test Apparatus - High Mass

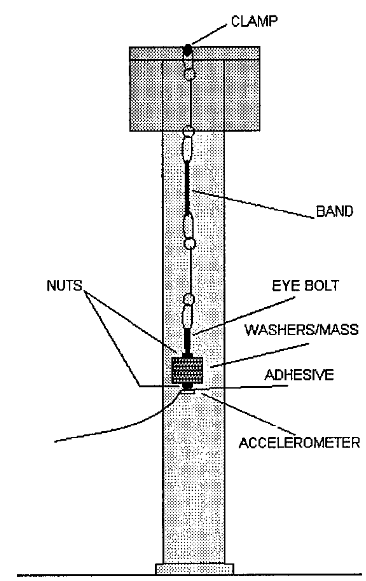


Figure 3.14 Loop Stiffness Test Apparatus - Low Mass

oscillation was of the same magnitude as that experienced when the set was on the excited array. The motion of the mass was measured with the accelerometer adhered to its' base.

In initial experiments the accelerometer utilized had a sensitivity of approximately 10 mV/g. This accelerometer was replaced with one that had a sensitivity of approximately

650 mV/g for the remainder of the tests, when it was found that the low acceleration values experienced during mass oscillation were barely above the noise floor for the initial accelerometer.

Six rubber bands were initially selected for each loop set. It was found that there was a significant degree of deviation in these first sets, ranging from ten to twenty five percent. This deviation is very likely due to the lack of high precision requirements in the manufacturing of rubber bands. To overcome this and reduce the deviation to more acceptable levels, multiple similar bands were tested for each set. Of these multiple bands, the six with the closest stiffness values were selected for the final set.

The accelerometer data was acquired with the HP E1421B Mainframe. The mainframe was controlled and setup through use of the MATLAB based Datascope 2.0 program. The data was sampled at a frequency of 64 Hz, a frequency well over two times the natural frequencies of the loop sets. 1024 data points were acquired for one oscillation decay. This allowed for a total sampling time of 16 seconds. This was ample time to observe the decay of the loop sets' oscillation.

As with the rib characterization, ERA techniques were utilized in the analysis of the time data. It was found that the frequency value increased for later times in the oscillation decay. To obtain a value for the oscillation frequency and the loop set damping, the values found throughout the decay were averaged.

For some of the loop sets, information from the later portion of the data was difficult to obtain. This was primarily due to two things; first, pendulum-like motions of the mass on the loop set and, second, incredibly small oscillation well below the noise floor of the accelerometer. Due to this, the latter portions of the decay were not analyzed. The decay data analyzed was analyzed from where the signal from the accelerometer remained within a $\pm 0.015 mV$ envelope. Starting at this point allowed a standardization of the data analyzed since the initial offsets of the masses varied.

The results of the experiment and data analysis can be found in Table 3.10.

The orange set provides the lowest coupling stiffness, and the red set provides the highest value. It can be seen that all of the coupling stiffness deviations are within five

Loop Set	Loop Number	Frequency (Hz)	Mass (g)	Stiffness (N/m)	Damping (%)
Yellow	1	2.19	210	39.8	2.26
Yellow	2	2.22	210	40.8	2.60
Yellow	3	2.22	210	40.8	2.20
Yellow	4	2.22	210	41.0	2.61
Yellow	5	2.24	210	41.7	2.28
Yellow	6	2.20	210	40.1	2.47
Mean		2.22	210	40.7	2.40
Standard Deviation (%)		0.759	0	1.52	6.87
Red	1	4.44	85	66.1	1.96
Red	2	4.34	85	63.3	2.88
Red	3	4.28	85	61.3	2.98
Red	4	4.43	85	65.9	2.63
Red	5	4.43	85	65.7	2.54
Red	6	4.29	85	61.6	2.90
Mean		4.37	85	64.0	2.65
Standard Deviation (%)		1.56	0	3.12	13.0
Green	1	2.42	195	45.2	2.17
Green	2	2.44	195	45.8	2.03
Green	3	2.39	195	44.1	1.78
Green	4	2.44	195	45.8	2.16
Green	5	2.41	195	44.6	1.73
Green	6	2.45	195	46.5	1.92
Mean		2.43	195	45.3	1.96
Standard Deviation (%)		0.910	0	1.82	8.80
Orange	1	3.11	90	34.3	2.91
Orange	2	3.13	90	34.8	3.47
Orange	3	3.12	90	34.6	3.21
Orange	4	3.06	90	33.3	2.59
Orange	5	3.12	90	34.7	3.13
Orange	6	3.05	90	33.0	3.02
Mean		3.10	90	34.1	3.05
Standard Deviation (%)		1.06	0	2.12	8.87

Table 3.10 Loop Set Stiffness Values

percent. However, there is significant deviation in the damping values for all of the sets. This variation falls back to the manufacturing quality of the rubber bands. It was attempted to reduce the variation, but the values shown in the table were the best possible with the available bands. These significant variations may effect localization behavior in the assembled array.

Whole Array Excitation. Chirp free decay excitation was utilized to generate response information on the array. One of the beams was chirped about the natural frequencies of the array (the first modal band to be more specific), and the response of all six was measured. This was completed for all six beams. The six SIMO data sets were then weaved together to form a pseudo MIMO set, which was then analyzed with ERA

techniques to determine the modal characteristics of the array. Only the decay portion of the data was analyzed. This same method was utilized in a study of compressor blades [11].

The chirp ranged from 14 to 20 Hz, for a total of 3.2 seconds (4096 points at a frequency of 1280 Hz). The data for the chirp period and the following 22.4 seconds of decay were taken for six ribs. In addition to accelerometer data, the excitation signal was measured. This signal was used to confirm alignment of the SIMO data sets. The voltage range for the chirp was 8 Volts. The accelerometer channel ranges were set at 0.2 Volts.

As stated previously, ERA analysis was conducted on the decay data. The start of the decay portion analyzed was at 0.71 seconds after the chirp signal ceased. This was selected in a fairly ad hoc manner. It was the 5000^{th} data point after the chirp commenced. It was found through trial and error that decimation of the data by a factor of 5 with a 250X120 Hankel matrix yielded high modal assurance criteria and consistent results with the modal frequencies. Damping values were fairly consistent for the ordered systems (i.e. those with inter-rib coupling). Typical values for the singular value cutoff point ranged between 30 and 40.

The method of calculating infinity/two norms and four/two norms, as detailed in Chapter 2, required a base set to compare the modes. The modes for the circulant six pendulum system were utilized. If the experimental system has perfectly ordered modes, their normalized value should be the same as that of the circulant modes. The mode shapes determined from the ERA analysis were first normalized and then compared to the base circulant modes.

Shown in Figures 3.15 through 3.18 are the mode shapes for the array with the various coupling levels. Tables 3.11 through 3.15 are the various parameters measured for those modes (frequency, damping, length scales, etc.). The tabular data is presented in sequence with the plotted mode shapes, this is done to lend an intuition of how the localization length scales compare to the actual deflection occurring.

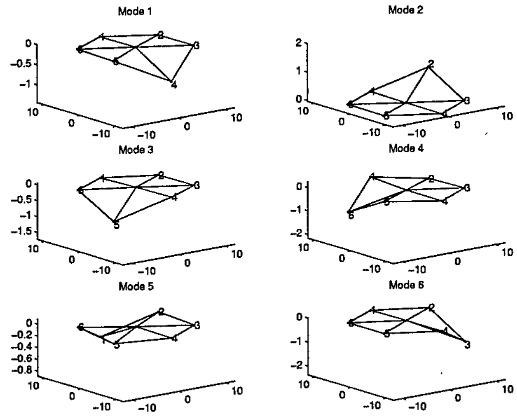


Figure 3.15 Bare Array Mode Shapes

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	17.39	17.44	17.53	17.59	17.62	17.87
Damping (%)	0.39	0.34	0.34	0.39	0.40	0.46
L_∞	0.41	0.58	0.50	0.50	0.58	0.41
L_{four}	0.17	0.25	0.25	0.26	0.25	0.17

Table 3.11 Bare Array Characteristics

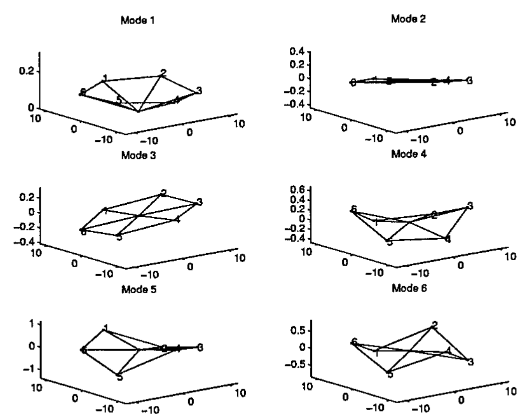


Figure 3.16 Array Mode Shapes - Orange Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	15.33	15.98	16.12	17.68	17.52	18.42
Damping (%)	0.40	0.39	0.36	0.36	0.34	0.29
L_∞	0.90	1.04	0.82	0.84	0.99	0.90
L_{four}	0.96	0.98	1.07	0.97	0.97	0.97

Table 3.12 Array Characteristics - Orange Coupling

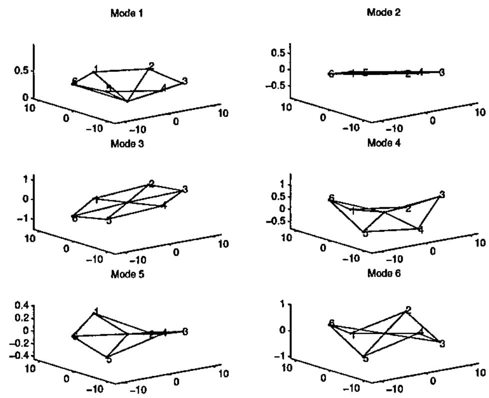


Figure 3.17 Array Mode Shapes - Yellow Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	14.05	15.77	15.89	19.27	19.11	20.77
Damping (%)	0.50	0.38	0.42	0.34	0.31	0.26
L_∞	0.91	1.08	0.83	0.85	1.12	0.95
L_{four}	0.97	0.99	1.05	1.00	1.00	1.00

Table 3.13 Array Characteristics - Yellow Coupling

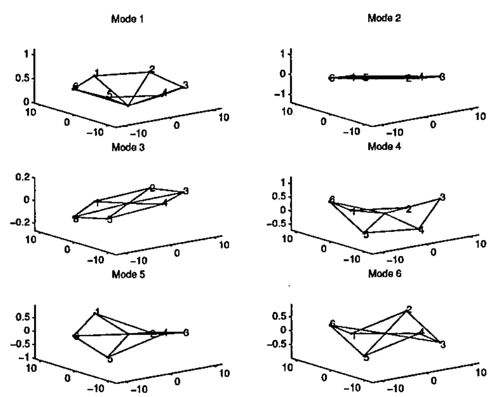


Figure 3.18 Array Mode Shapes - Green Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	14.47	15.9106	16.0345	18.9459	18.7340	20.2032
Damping (%)	0.70	0.41	0.46	0.36	0.34	0.28
L_∞	0.91	1.05	0.84	0.84	1.12	0.96
L_{four}	0.98	0.98	1.07	1.00	1.00	1.00

Table 3.14 Array Characteristics - Green Coupling

	Bare	Orange	Yellow	Green
L_{MAC}	0.0067	0.33	0.38	0.26
$\Delta\lambda$	0.057	0.44	1.18	0.95

Table 3.15 Additional Array Characteristics

The reader may notice that the red coupling set was not considered here. When the red coupling set was constructed, the intention was to create a low coupling set. To accomplish this, the bands were connected so that they had minimal extension and were on the verge of sagging when attached to the system. This was the undoing of that set: the looseness resulted in a flapping motion, essentially a string mode, when the array was excited. The flapping affected the data taken to the point that the modes of the array were difficult/impossible to distinguish. Due to this, the red coupling set was not utilized for further analysis.

Something important to note is that the mode shapes attained for this and the following portions of the experiment were complex. When the eigenvectors for the nearly global systems were scaled by the first value in each eigenvector, the modal complexity was severely reduced. For those modes, the modal complexity is most likely due to damping present in the system. However, this was not the case for the localized modes. The localized modes maintained a significant degree of complexity after scaling. Why this occurred is unknown. It may be due to the modes actually being complex or it may be caused by measurement/analysis artifacts. Complexity in localized modes has been seen in other experimental efforts, but its exact cause is undetermined [12]. Factors in this particular test that may have led to modal complexity are:

1. Phase error due to operation in the low end of the operating range of the ENDEVCO® accelerometers. The accelerometers can have a phase error of approximately five percent in the region of interest for the tests conducted [10].
2. Difference in the driving levels of the individual PZT causing the SIMO weave into MIMO to be a less than perfect assumption due to uneven driving levels.
3. The six data vectors for each rib did not have the same boundary conditions in that the five of the vectors had the open/open PZT boundary condition and one had the open/connected to source boundary condition.

4. The chirp responses were aligned based on the input voltage to the PZT and not on the force actually exerted. Lag may have existed causing the complex modes [3].

It was though the combination of the closely spaced modes and the small amount of spatial data may have caused the complex modes[3]. To determine if this was possibly the reason, two accelerometers were placed on each rib and data was taken with the yellow coupling set on the array. The modes found were also complex. The existence of complex modes is consistent with other experimental results [12] and is an area for future study.

Mistuning Sets. The mistuning masses that were utilized for this experiment were clamp-on lead fishing sinkers. Fifty sinkers were weighed at one time and found to have a mass of 54.624 grams. This yielded a mean mass of 1.09 grams per sinker. Because of the discrete nature of the mistuning masses, a discrete method of generating mistuning sets was necessary.

To generate the effect of negative mass, masses were added to the bare system. The base system became the bare system with 3 masses clamped on. This allows seven possible values for the ribs mass mistuning ranging from -3 to +3 masses. This physically translates to no masses or six masses clamped to the beam tip. The limiting factor on the range of mistuning was the amount of mass that could be added. Addition of mass results in a decrease of natural frequency. The bare system without additional mass has modes around 17 Hz. This is already in the low operating range of the accelerometers. The addition of more than three grams resulted in severely degraded accelerometer data. The array modal data for the three coupling levels with addition of three masses is shown in Tables 3.16, 3.17 and 3.18. These results were obtained with the same methods used for the array excitation previously. The chirp signal ranged from 8 to 14 Hz to accommodate for the change in modal frequencies.

Having the ability to range between ± 3 masses meant that three mistuning levels could be investigated, low mistuning at ± 1 mass, medium at ± 2 masses and high at ± 3 masses. Mistuning sets with means of zero and bell-curve-like behavior were desired to simulate manufacturing conditions.

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	11.07	11.48	11.65	12.62	12.49	13.05
Damping (%)	0.25	0.32	0.32	0.36	0.22	0.29
L_∞	0.92	1.09	0.82	0.82	0.96	0.88
L_{four}	0.96	0.99	1.08	0.92	0.94	0.95

Table 3.16 Orange Coupling Set +3 Mass Array Characteristics

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	10.02	11.22	11.37	13.67	13.54	14.67
Damping (%)	0.64	0.38	0.14	0.28	0.32	0.26
L_∞	0.93	1.11	0.84	0.83	1.07	0.97
L_{four}	0.98	1.00	1.08	0.98	1.00	1.00

Table 3.17 Yellow Coupling Set +3 Mass Array Characteristics

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	10.32	11.34	11.46	13.46	13.29	14.30
Damping (%)	0.41	0.43	0.38	0.27	0.25	0.22
L_∞	0.94	1.12	0.85	0.83	1.08	0.97
L_{four}	0.98	1.00	1.08	0.97	1.00	1.00

Table 3.18 Green Coupling Set +3 Mass Array Characteristics

The first step in generating the mistuning sets was selecting a target standard deviation for the ± 3 masses set. A standard deviation of two was selected. The second step was setting the bin boundaries. These were set at ± 0.5 of the values they bracketed. With the bin boundaries and the standard deviation and mean (a mean of zero) fixed, all that was needed was the total probability of falling within a specific bin. To determine this, the z values for a normal curve were determined for the bin boundaries and the associated $\Phi(z)$ values were determined. These values are shown in Table 3.19. The z values for the bin borders were determined with Equation 3.8, where x is the bin border value, μ is the mean and σ is the standard deviation.

$$z = \frac{x - \mu}{\sigma} \tag{3.8}$$

Bin Border	-3.5	-2.5	-1.5	-0.5	0.5	1.5	2.5	3.5
z	-1.75	-1.25	-0.75	-0.25	0.25	0.75	1.25	1.75
$\Phi(z)$	0.0402	0.1060	0.2270	0.4014	0.5986	0.7730	0.8940	0.9598

Table 3.19 Normal Curve Values Utilized to Generate ±3 Mistuning Set

The $\Phi(z)$ values were utilized to generate cumulative probabilities for the bins centered about the discrete values. A random number generator was then utilized to generate uniformly distributed values between 0 and 1. It was then determined what range of cumulative probabilities this value fell within. The value was assigned the value of the bin whose cumulative probability range it fell within. The random number generator completed this process 25,000 times to generate the discrete distribution. 25,000 was selected because the mean and standard deviation of the generated set remained constant at that point. The standard deviation changed from the targeted value of 2 to 1.8 due to the discretization.

The ±3 values were then eliminated from the set generated and the new standard deviation was determined. It was found to be 1.3. The ±2 values were eliminated, and the new set generated had a standard deviation of 0.8. This was done for the ±1 and ±2 sets so they would have bins with similar proportions in size to the ±3 set, thus allowing cross over sets between the two. The z and $\Phi(z)$ values were determined for the ±1 and ±2 sets given their standard deviations of 1.3 and 0.8 respectively. These values are shown in Tables 3.20 and 3.21.

Bin Border	-2.5	-1.5	-0.5	0.5	1.5	2.5
z	-1.25	-0.75	-0.25	0.25	0.75	1.25
$\Phi(z)$	0.0273	0.1254	0.3504	0.6496	0.8754	1

Table 3.20 Normal Curve Values Utilized to Generate ±2 Mistuning Set

Bin Border	-1.5	-0.5	0.5	1.5
z Value	-0.75	-0.25	0.25	0.75
$\Phi(z)$	0.0359	0.2662	0.7738	1

Table 3.21 Normal Curve Values Utilized to Generate ±1 Mistuning Set

Due to time limitations, it was not possible to take data on the array with numerous mistuning sets. Fifteen mistuning subsets of six (one for each rib) were generated with

these Normal curve values. The ±3 set was generated first. Due to the limited number of random values generated, 90 to be exact, it was difficult to obtain a symmetric curve. Numerous generations were completed before an acceptable curve/distribution was found. The 15 subsets that composed the ±3 set were then analyzed to find if any of them would fall within the ±2 or ±1 sets. This was done so that testing time would be reduced with the cross over. The ±2 and ±1 sets were generated in a similar manner. The distributions for all three sets are shown in Figure 3.19. The set means and standard deviations are shown in Table 3.22. The actual subsets that composed the sets are shown in Table 3.23.

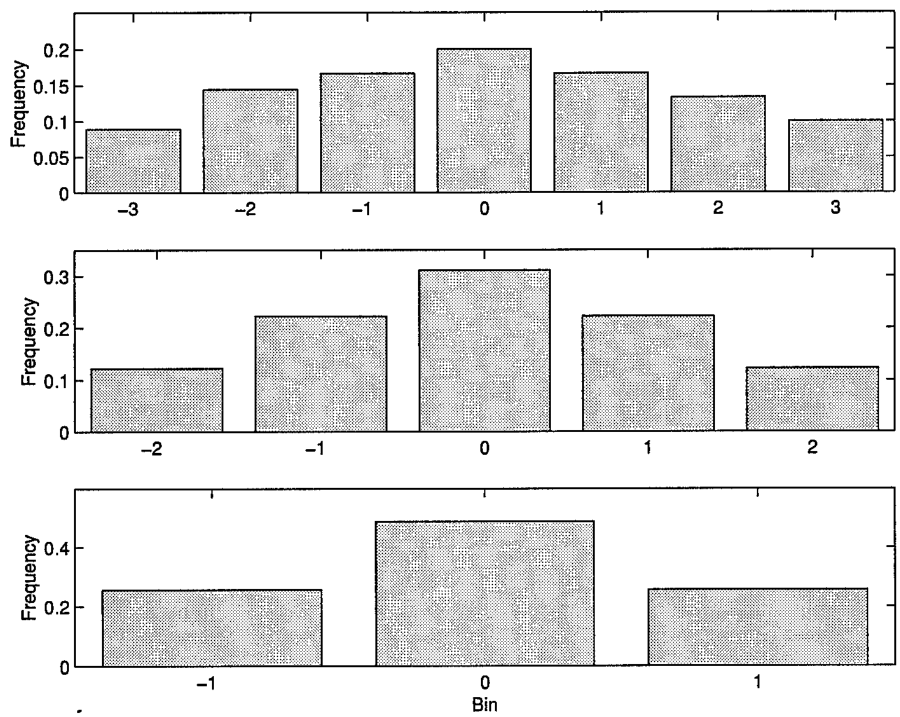


Figure 3.19 Curves For Mistuning Set Distributions

Set	Mean	Standard Deviation
±3	0.0111	1.7732
±2	0	1.1926
±1	0	0.7149

Table 3.22 Mistuning Set Means and Standard Deviations

Set Number	Parent Set	Value 1	Value 2	Value 3	Value 4	Value 5	Value 6
1	± 3	-2	3	0	1	-2	1
2	± 3	-1	1	-2	-2	0	3
3	± 2 *and* ± 3	0	2	0	2	2	-1
4	± 3	0	-1	-3	-1	-1	-1
5	± 3	-1	-2	-3	-1	1	-1
6	± 2 *and* ± 3	1	-2	0	1	1	-2
7	± 3	-2	-1	-3	2	-2	2
8	± 3	0	0	-2	0	-1	-3
9	± 3	0	-2	2	1	-3	0
10	± 3	1	1	1	3	-1	3
11	± 2 *and* ± 3	1	1	0	0	2	2
12	± 3	-3	3	-3	0	3	3
13	± 3	-2	-2	-1	3	2	2
14	± 2 *and* ± 3	-1	0	0	2	0	1
15	± 3	0	3	1	-3	2	-1
16	± 2	-2	1	0	2	0	0
17	± 1 *and* ± 2	0	0	1	-1	-1	0
18	± 1 *and* ± 2	0	1	0	-1	-1	-1
19	± 2	-1	0	1	-1	-1	-2
20	± 2	1	0	0	-2	0	-2
21	± 1 *and* ± 2	1	0	-1	0	0	-1
22	± 2	0	-2	-2	2	1	1
23	± 1 *and* ± 2	-1	1	1	-1	1	0
24	± 2	-1	2	-2	-2	-1	0
25	± 1 *and* ± 2	-1	-1	0	0	1	-1
26	± 2	2	2	1	1	-2	-1
27	± 1	1	0	1	1	0	0
28	± 1	-1	0	0	1	0	0
29	± 1	0	-1	-1	-1	1	1
30	± 1	0	0	1	0	-1	0
31	± 1	0	1	0	1	0	0
32	± 1	1	1	-1	0	0	0
33	± 1	0	0	0	0	0	-1
34	± 1	0	0	-1	1	0	1
35	± 1	-1	0	0	0	0	0
36	± 1	-1	1	1	-1	0	1

Table 3.23 Mistuning Set Means and Standard Deviations

Mistuning Results. A sampling of the raw results obtained from mistuning the array for various mistuning levels for different levels of coupling are presented here. All of the raw results, modal characteristics and experimental setup parameters, are given in Appendix B. Also included in this section are the trends that were observed in the experimental data.

Mistuned Array Results. The same excitation and analysis methods utilized for the tuned array with 3 grams added to each rib was utilized for the mistuned system. The data was taken in three blocks corresponding to the three coupling sets; however, to reduce some experimental error, the mistuning runs were randomized.

As with the "tuned" system, the modes of the mistuned system were compared to those of the circulant six pendulum system. However, due to the potential of the order of the modes switching, each set of modes was optically compared to the best modes (through both static and animated means) to determine which base mode they correlated with.

Two repeats were completed for each coupling level to see what deviation existed, if any, between what should be the same test. The results for all of the repeats are shown in Tables 3.24 through 3.29. As can be seen, the results were repeatable.

Run	f_1(Hz)	f_2(Hz)	f_3(Hz)	f_4(Hz)	f_5(Hz)	f_6(Hz)	$L_{\infty 1}$	$L_{\infty 2}$	$L_{\infty 3}$	$L_{\infty 4}$	$L_{\infty 5}$	$L_{\infty 6}$
1	10.93	11.72	11.81	12.62	14.71	14.92	0.491	0.933	0.549	0.713	0.680	0.498
2	10.92	11.72	11.80	12.62	14.70	14.92	0.491	0.934	0.575	0.717	0.678	0.493
3	10.91	11.72	11.81	12.62	14.70	14.92	0.491	0.937	0.554	0.718	0.673	0.487

Table 3.24 Results For 3 Mistuning Runs, Orange Coupling, Mistuning Set 20

Run	f_1(Hz)	f_2(Hz)	f_3(Hz)	f_4(Hz)	f_5(Hz)	f_6(Hz)	$L_{\infty 1}$	$L_{\infty 2}$	$L_{\infty 3}$	$L_{\infty 4}$	$L_{\infty 5}$	$L_{\infty 6}$
1	10.93	11.72	11.81	12.62	14.71	14.92	0.419	0.690	0.563	0.568	0.806	0.564
2	10.92	11.72	11.80	12.62	14.70	14.92	0.418	0.690	0.562	0.570	0.807	0.556
3	10.91	11.72	11.81	12.62	14.70	14.92	0.420	0.692	0.563	0.571	0.806	0.562

Table 3.25 Results For 3 Mistuning Runs, Orange Coupling, Mistuning Set 24

Run	f_1(Hz)	f_2(Hz)	f_3(Hz)	f_4(Hz)	f_5(Hz)	f_6(Hz)	$L_{\infty 1}$	$L_{\infty 2}$	$L_{\infty 3}$	$L_{\infty 4}$	$L_{\infty 5}$	$L_{\infty 6}$
1	9.51	12.09	10.84	14.19	14.65	16.88	0.504	0.735	0.565	0.576	0.883	0.588
2	9.51	12.09	10.86	14.21	14.67	16.92	0.500	0.737	0.565	0.579	0.891	0.590
3	9.50	12.10	10.85	14.17	14.63	16.85	0.500	0.733	0.564	0.572	0.884	0.589

Table 3.26 Results For 3 Mistuning Runs, Yellow Coupling, Mistuning Set 2

Run	f_1(Hz)	f_2(Hz)	f_3(Hz)	f_4(Hz)	f_5(Hz)	f_6(Hz)	$L_{\infty 1}$	$L_{\infty 2}$	$L_{\infty 3}$	$L_{\infty 4}$	$L_{\infty 5}$	$L_{\infty 6}$
1	9.87	10.81	11.29	13.40	13.11	14.25	0.777	0.923	0.750	0.700	0.951	0.753
2	9.87	10.81	11.29	13.41	13.11	14.26	0.784	0.919	0.752	0.704	0.955	0.748
3	9.85	10.80	11.29	13.43	13.14	14.29	0.784	0.922	0.754	0.704	0.951	0.748

Table 3.27 Results For 3 Mistuning Runs, Yellow Coupling, Mistuning Set 31

Run	f_1(Hz)	f_2(Hz)	f_3(Hz)	f_4(Hz)	f_5(Hz)	f_6(Hz)	$L_{\infty 1}$	$L_{\infty 2}$	$L_{\infty 3}$	$L_{\infty 4}$	$L_{\infty 5}$	$L_{\infty 6}$
1	11.20	12.22	13.03	14.98	14.13	18.30	0.607	0.921	0.820	0.758	0.956	0.430
2	11.22	12.20	13.03	14.94	14.09	18.21	0.607	0.929	0.803	0.758	0.943	0.430
3	11.26	12.20	13.04	14.89	14.06	18.19	0.602	0.922	0.806	0.754	0.934	0.432

Table 3.28 Results For 3 Mistuning Runs, Green Coupling, Mistuning Set 4

Run	f_1(Hz)	f_2(Hz)	f_3(Hz)	f_4(Hz)	f_5(Hz)	f_6(Hz)	$L_{\infty 1}$	$L_{\infty 2}$	$L_{\infty 3}$	$L_{\infty 4}$	$L_{\infty 5}$	$L_{\infty 6}$
1	10.51	11.69	11.43	13.31	13.63	14.56	0.822	1.015	0.838	0.848	0.972	0.551
2	10.53	11.70	11.42	13.32	13.62	14.56	0.820	0.998	0.847	0.828	0.980	0.555
3	10.57	11.70	11.44	13.24	13.59	14.48	0.820	0.998	0.847	0.828	0.980	0.555

Table 3.29 Results For 3 Mistuning Runs, Green Coupling, Mistuning Set 35

Shown in Figures 3.20 through 3.23 are the least and most localized modes for each of the coupling sets. These are shown here, along with there associated infinity/two and four/two norm values so that the reader has an idea of how these parameters correlate with the physical distortion of the mode shapes. For all three levels of coupling, set 33 provides the least localization. For the yellow and green coupling set 12 has the highest localization, and set 7 has the highest localization for the orange coupling.

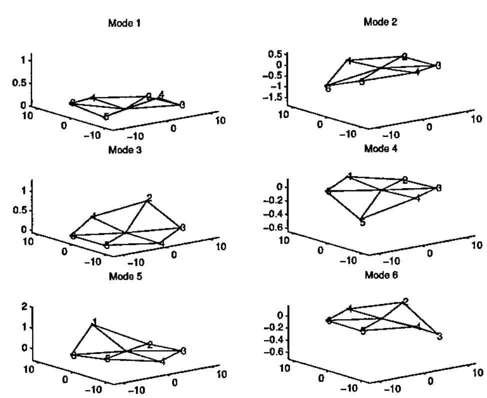


Figure 3.20 Highest Localization For Orange Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	10.32	10.49	12.76	14.70	14.95	17.28
L_{∞}	0.43	0.62	0.53	0.51	0.62	0.41
L_{four}	0.20	0.32	0.31	0.27	0.32	0.18

Table 3.30 Highest Localization For Orange Coupling - Characteristics

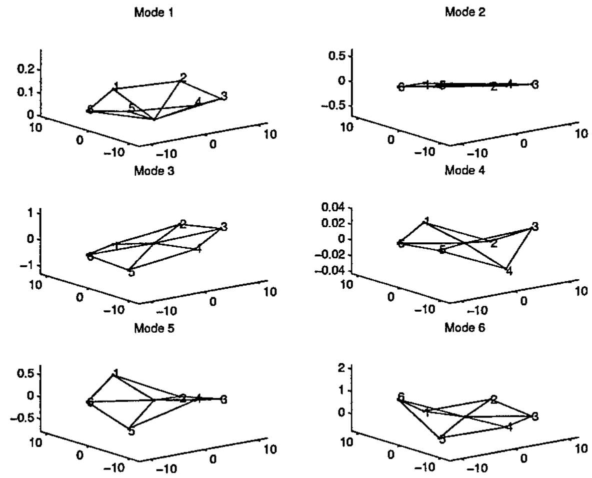


Figure 3.21 Lowest Localization For Orange Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	11.19	11.51	11.90	12.76	12.43	13.47
L_{∞}	0.76	1.05	0.94	0.74	1.04	0.46
L_{four}	0.81	0.98	1.12	0.80	0.98	0.26

Table 3.31 Lowest Localization For Yellow Coupling - Characteristics

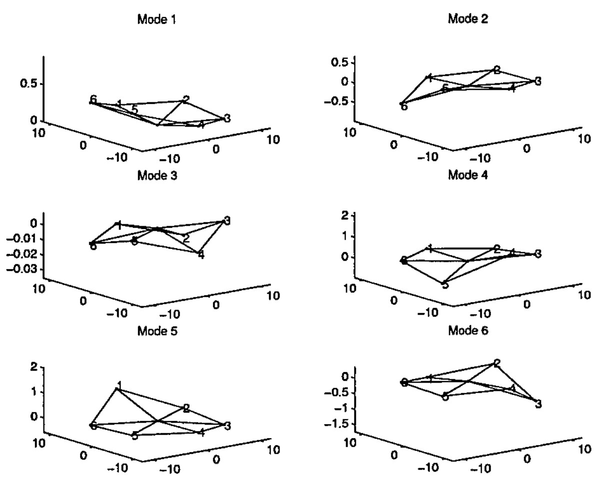


Figure 3.22 Highest Localization For Yellow Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	9.01	10.67	9.81	12.53	17.80	18.30
L_{∞}	0.61	0.82	0.54	0.57	0.60	0.44
L_{four}	0.46	0.70	0.34	0.40	0.29	0.23

Table 3.32 Highest Localization For Yellow Coupling - Characteristics

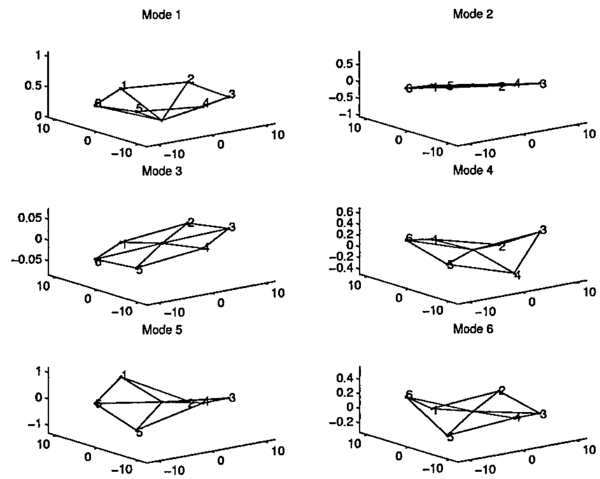


Figure 3.23 Lowest Localization For Yellow Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	10.24	11.30	11.69	13.98	13.50	15.06
L_∞	0.84	1.05	0.95	0.80	1.08	0.56
L_{four}	0.93	0.99	1.20	0.91	0.99	0.48

Table 3.33 Lowest Localization For Yellow Coupling - Characteristics

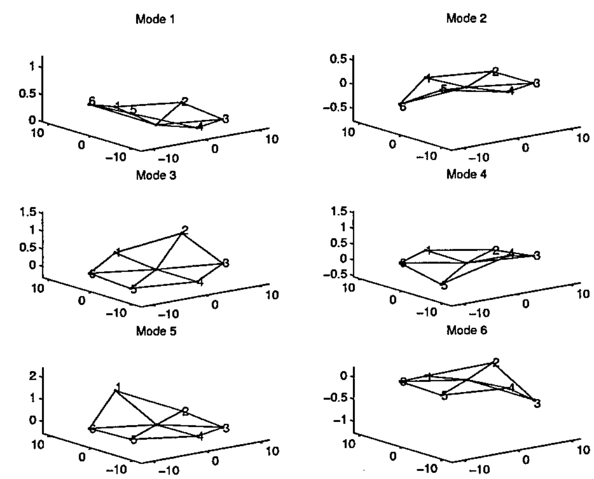


Figure 3.24 Highest Localization For Green Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	9.18	10.65	9.80	12.32	17.63	18.08
L_∞	0.59	0.81	0.53	0.55	0.59	0.45
L_{four}	0.43	0.66	0.31	0.36	0.28	0.23

Table 3.34 Highest Localization For Green Coupling - Characteristics

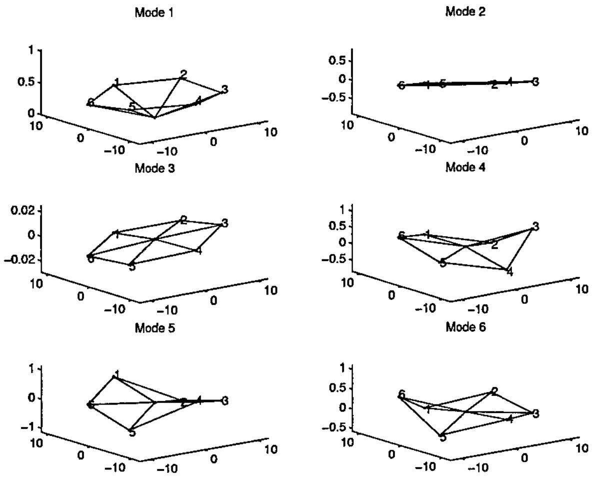


Figure 3.25 Lowest Localization For Green Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	10.49	11.38	11.77	13.73	13.25	14.6165
L_{∞}	0.86	1.07	0.97	0.79	1.12	0.54
L_{four}	0.92	0.99	1.18	0.89	1.00	0.44

Table 3.35 Lowest Localization For Orange Coupling - Characteristics

Localization Versus Mistuning. Plots of the four norm/two norm and infinity norm/two norm of the mode vs. mass mistuning were accomplished. It was found that between the choices of infinity norm/two norm of the mass, four norm of the mass, two norm of the mass and standard deviation of the mass, the standard deviation produced the least scatter. An example of the scatter is shown in Figure 3.26. The third mode infinity/two norm values for the yellow set are plotted against the various mass mistuning parameters. Of all the parameters used for mass mistuning, the standard deviation appears to yield a tighter fit. Additionally, when linear fits were attempted, lower error resulted in the fits with the standard deviation of the mistuning.

Due to the number of points available and the degree of scatter present, it was determined that only a linear fit would be attempted. This will at least show if the data found either monotonically decreases or increases as a function of the input parameters of system mistuning and coupling.

Plotted in Figures 3.27 and 3.28 are the means of the localization scales for the various coupling sets versus the increasing mass mistuning. The relationship appears to

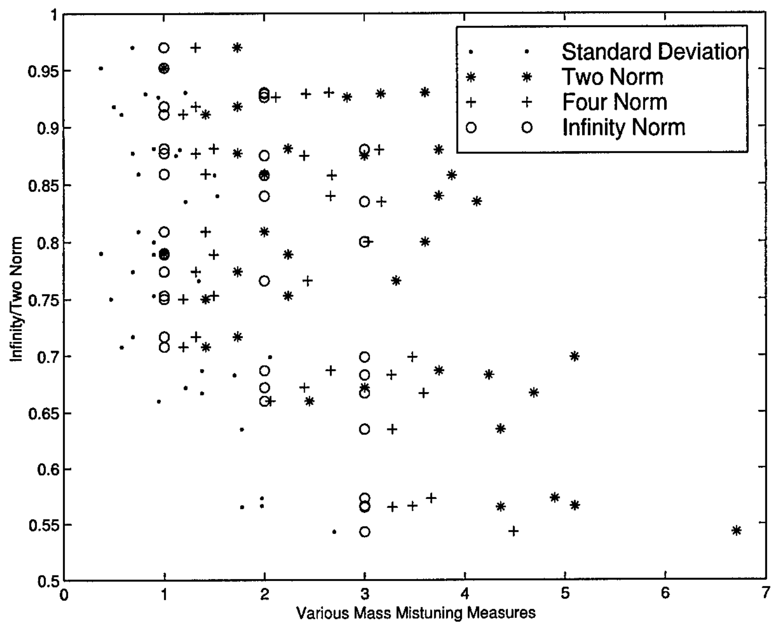


Figure 3.26 Infinity Norm/Two Norm vs. Mistuning for the Three Coupling Levels

be linear with a negative slope. This enforces the idea that as mistuning increases modal order decreases.

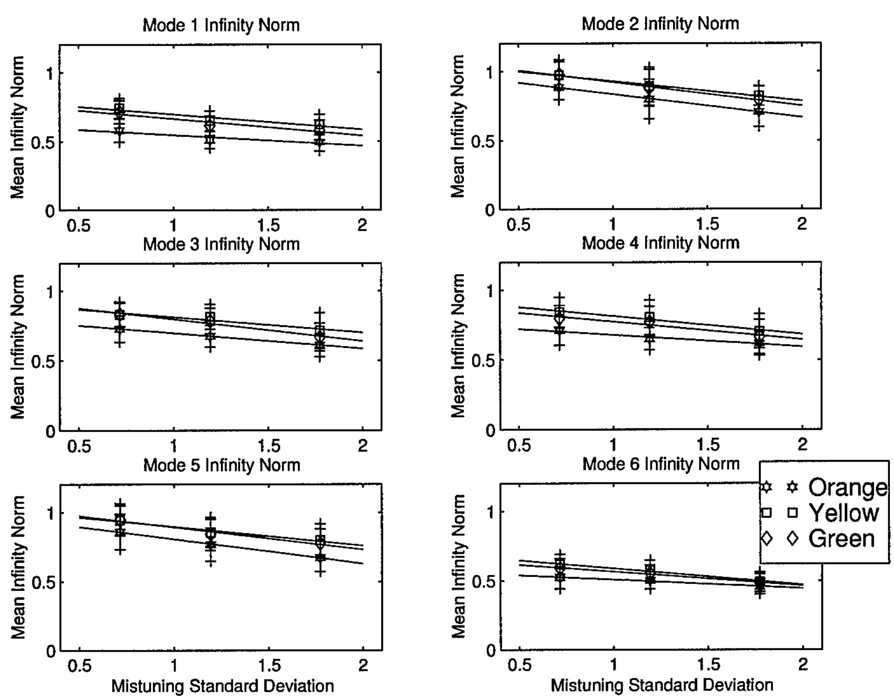


Figure 3.27 Infinity Norm/Two Norm vs. Mistuning for the Three Coupling Levels

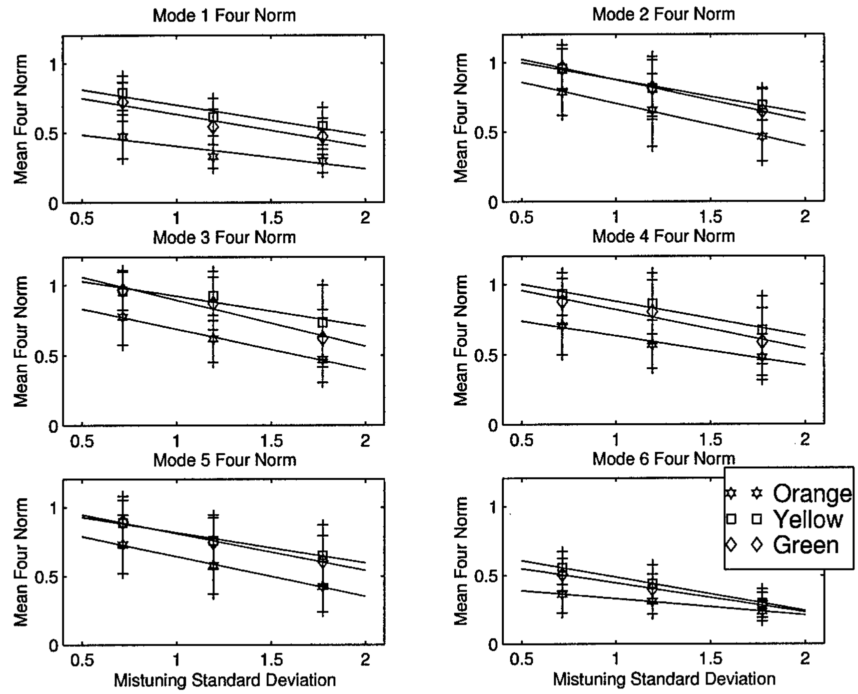


Figure 3.28 Four Norm/Two Norm vs. Mistuning for the Three Coupling Levels

Mistuning of Specific Modes. The modes at the beginning and end of the band experience the worst degree of localization. Shown in Table 3.36 are the mean infinity norms for each of the modes at the three coupling levels. It can be seen that in all cases Modes 1 and 6 experience the most localization. This result agrees well with previous research [9],[15]. Additionally, Mode 6 experiences the most localization.

Coupling	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Orange	0.53	0.79	0.67	0.66	0.76	0.49
Yellow	0.67	0.89	0.78	0.77	0.86	0.55
Green	0.63	0.88	0.75	0.74	0.85	0.54

Table 3.36 Mean Infinity Norm Values

The Effects of Coupling On Mistuning. The degree of localization decreases from low coupling to medium coupling. However, for the majority of the modes measured, between the medium to high coupling there is an increase in localization. This result is counter to the expected behavior. It was suspected, prior to data collection, that

localization would monotonically decrease with increased coupling. This may truly be a phenomena that occurs with real systems; however, it is uncertain though with the amount of data present. It is speculation with the amount of data present, but this decrease in localization with an increase in coupling may be caused by the mistuning present in the coupling sets. That mistuning, aside from the change in coupling level, is the only difference between the two sets. Additionally, if the modal bandwidth of the ordered system is utilized as a measure of the system's susceptibility to localization, the base yellow system had a higher bare system modal band width than the green.

The means for the respective modes for the three mistuning levels (sets 1, 2 and 3) are plotted in Figures 3.29 and 3.30. The decrease and increase in localization with increasing stiffness can be seen particularly well in modes 1 and 6.

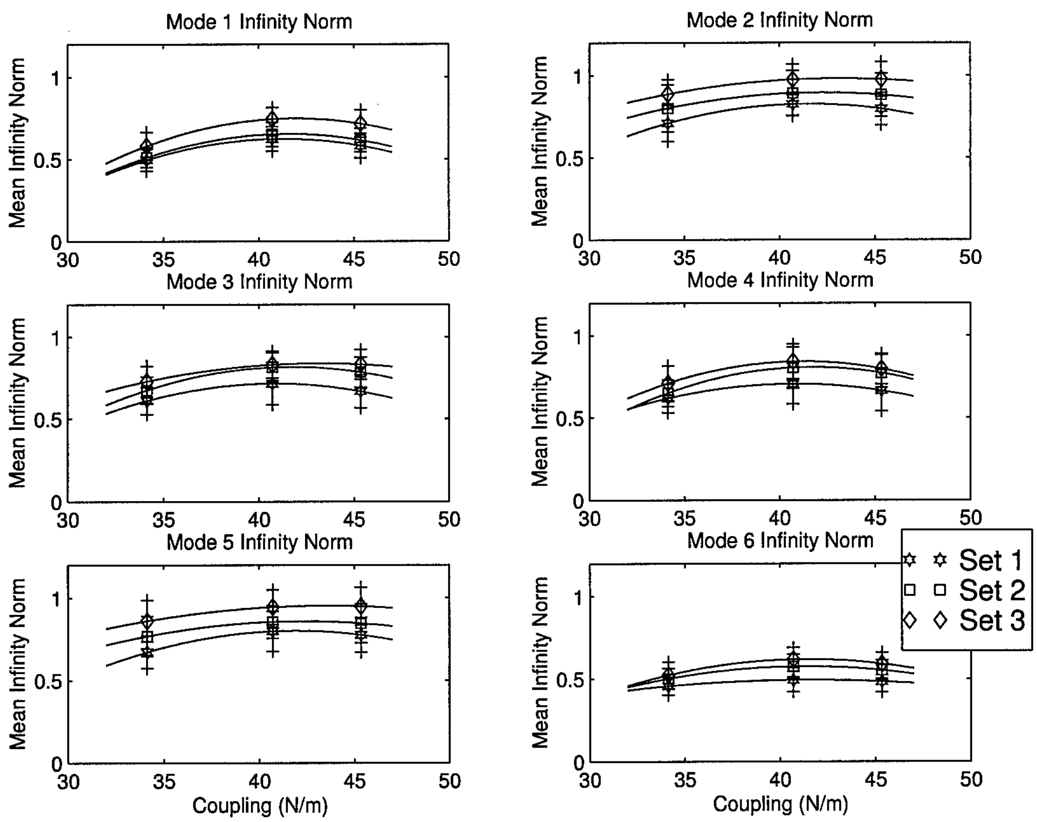


Figure 3.29 Infinity Norm/Two Norm for the Six Modes vs. Coupling

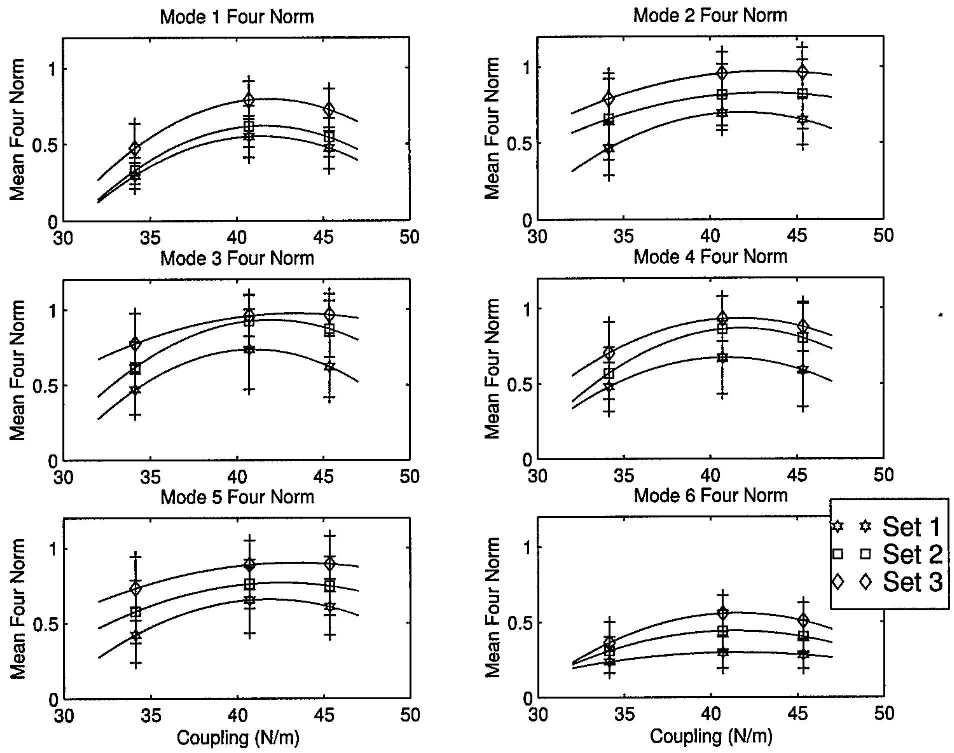


Figure 3.30 Four Norm/Two Norm for the Six Modes vs. Coupling

Modal Bandwidth vs. Mistuning. The modal bandwidth increases as the standard deviation of the mistuning set increases. This is shown in Figure 3.31. As with the localization versus coupling, this factor has higher values for the yellow than the green.

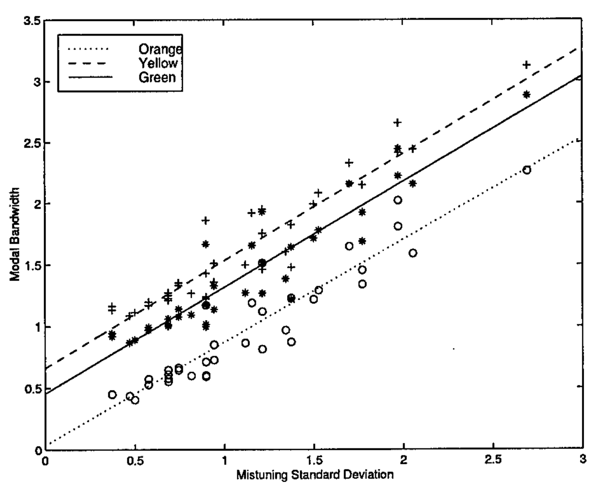


Figure 3.31 Modal Bandwidth vs. Mistuning for the Three Coupling Levels

Effects of Mistuning Only One Rib. The tuned array, with 3 weights attached to each rib, was mistuned by adding and then subtracting 3 weights from rib 4. This mistuning scheme was tested for the three coupling levels. This yielded some interesting results.

When mass was added to the system, the first mode experienced the most localization. This is probably due in part to the additional mass lowering the frequency of the mistuned rib. The sixth mode experienced localization to a more severe degree when mass was removed from the system. The average four norm/two norm value for the first mode when mass was added was 0.57, when mass was removed the average for mode six was 0.42.

In addition to the somewhat targeted localization, another result was noted. When mass was added to the system, modes 2 and 3 switched order. When mass was subtracted, modes 4 and 5 switched order. The results for the array for both conditions, one rib mistuned high and one rib mistuned low, are shown in Tables 3.37 and 3.38.

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	10.19	11.48	11.28	12.15	12.48	12.91
Damping (%)	0.29	0.42	0.31	0.34	0.24	0.24
L_{four}	0.46	1.05	0.88	0.83	0.97	0.71
L_{∞}	0.26	0.98	0.96	0.80	0.94	0.67

Table 3.37 Array Modal Behavior With One Rib Mistuned High - Orange Coupling

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency (Hz)	11.16	11.48	11.93	12.87	12.50	17.27
Damping (%)	0.24	0.32	0.30	0.26	0.28	0.39
L_{four}	0.80	1.09	0.83	0.80	0.98	0.41
L_{∞}	0.79	1.01	0.80	0.85	0.94	0.17

Table 3.38 Array Modal Behavior With One Rib Mistuned Low - Orange Coupling

PZT Coupling Results. PZT experiences deflection when supplied with voltage. Additionally, it outputs voltage when deflected. This output of voltage was utilized to electronically couple the ribs of the array. System actuation was accomplished with the outer pair of PZT. This left the inner pair free. When the ribs were excited, this meant that both pairs of PZT were undergoing deflection. For the mistuning cases detailed

above, the inner pair was left alone with open leads. For the experiment described below, the inner pairs of PZT were connected with a parallel circuit. The physical device utilized to accomplish this is shown connected to the BNC board in Figure 3.32.

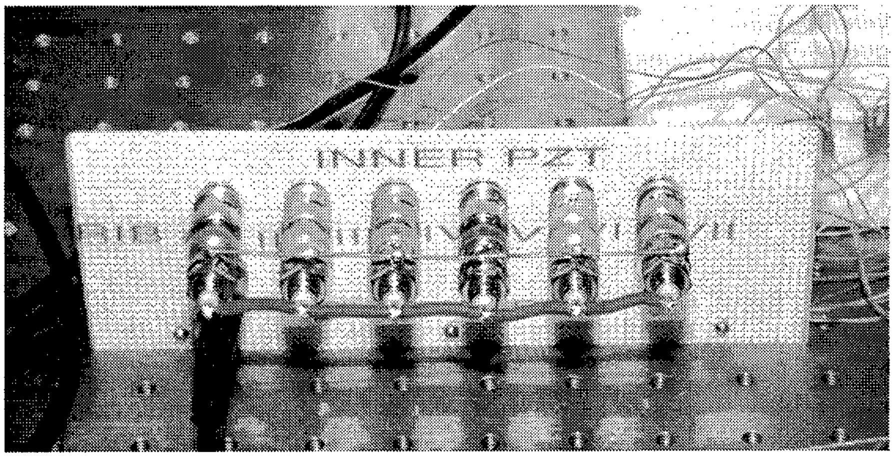


Figure 3.32 Parallel Wiring Utilized To Couple PZT Pairs

This electronic coupling serves as a means of distributing the mechanical energy of the system. Since localization can be reduced if system coupling is increased [15], this means of providing additional coupling was of interest.

Testing was completed on the array for all coupling levels (bare, orange, yellow and green) with and without the parallel circuit attached. The array tests were performed without the addition of three masses, unlike the mistuning runs. The signal generation and analysis techniques for these tests was the same as that used for the array characterization when no mass was added.

There was a slight change observed in the degree of localization for the bare set. The mean increase in the four/two norm was 0.02. Hence, there was a decrease, although slight, in the system localization. No substantial change was seen in the degree of localization for the coupled sets. For all of coupling levels and the bare system an average overall decrease of 0.05 Hz was seen in the modal frequencies.

This minimal change may be due to the low PZT coupling factor. The PZT coupling factor is a measure of the coupling that exists between the PZT and the structure, and

it indicates how efficient the electromechanical transfer is for a particular mode. It is determined with the relation shown in Equation 3.9.

$$k_{ij}^2 = \frac{\omega_D^2 - \omega_E^2}{\omega_E^2} \tag{3.9}$$

Where ω_D is the natural frequency of the rib when both sets of PZT leads are left open and ω_E is the natural frequency when the coupling bare leads are twisted together. The coupling factor for the PZT was 0.0154 for the inner and 0.0152 for the outer, both low values. It may be worth future research endeavors to see if enhancing the PZT coupling with a resonant shunting device (an electric circuit that amplifies the voltage over a specific frequency band) would improve the localization reduction.

Localization Measures. The infinity/two norm and the four/two norm provided similar trends. The biggest difference between the two parameters for the purposes of the experiment conducted was that the infinity/two norm was far simpler to calculate.

As for the condition number of the MAC matrix, there was no apparent trend. The value does not appear at this time to be a good measure of localization.

Summary

The details of experiments conducted on an actual space-like structure were discussed. The results of these experiments showed how localization in a real structure was effected by the degree of system mistuning and the level of coupling.

As expected, localization was found to increase with increasing mistuning. Counter to expectations, the localization decreased and then increased as the coupling level increased. This result may be caused by the mistuning present in the coupling sets, a factor not accounted for.

Unfortunately it was found that the addition of passive PZT coupling had minimal effect on the system behavior. The use of PZT is worthy of further research though, as will be discussed in the next chapter.

One of the more interesting results seen was the targeted localization that occurred when mass was either added to or removed from the system. The addition or subtraction of mass to one of the six ribs yielded a lower or higher frequency for that rib. That change in that individual rib then targeted either the first mode for mass addition or the last mode for mass subtraction.

These results along with the results of the numerical simulations are expanded upon, to include comparison, in the next chapter.

IV. Results and Recommendations

Presented here is a summary of the results given in Chapters 2 and 3. The purpose of this chapter is to point out the significance of those results and to summarize them. Additionally, presented in this chapter are areas pertinent to this research that require further work.

Results

Numerical Results. Two simple systems were considered. Each system was mistuned for three coupling levels and two hundred mistuning levels. Monte Carlo simulations were conducted at each coupling/mistuning level. The results of these simulations are enumerated below:

1. Overall, the relation between the standard deviation of the system localization to the standard deviation of the mistuning was found to follow a near linear increasing stage early on followed by a leveling off and a decrease that then experienced a leveling off. The significance of this behavior is that for low levels of mistuning, where the near linear behavior is observed, both fully extended and local systems are present about the mean behavior. However, as mistuning increases, the probability of the system behavior being the same as the mean value for all of the sets, which is localized behavior dependent on the system coupling, is very high.

2. System coupling was found to have a significant effect on this trend. For the three levels of coupling observed, the behavior ranged from seeing the entire trend for low coupling (increase - level - decrease - level) to seeing only the linearly increasing portion for the higher coupling levels.

3. The two length scales, the Infinity/Two and the Four/Two norm based measures were compared. For this portion of the thesis it was found that the Four/Two norm provided a better measure than the Infinity/Two Norm. The Infinity/Two norm results were at times overly choppy. Also, the Infinity/Two norm would provide

optimistic (instead of worst case as anticipated) characterization of the system. This is seen in Figure 2.22, where the Infinity/Two norm indicates that the system becomes further extended.

Experimental Results. An actual cyclic structure was tested. The substructures of the system were characterized, and disorder, typically below 5% was found to be present. When the system as a whole, without any level of coupling, was tested, severe localization was present. The modal energy for each of the six modes observed was focused at an individual substructure.

When three different levels of inter-substructure coupling were added, the individual modes of the system became nearly global or extended beyond the global modes. The coupling present was sufficient to increase the coupling to disorder ratio to the point where localization was no longer a concern.

Then the 'global' systems, the base system with some level of coupling added, were mass mistuned at three levels that represented a mistuning of 4.9, 8.2 or 12.2 percent. Multiple mistuning sets were tested at each level of mistuning to account for the probabilistic nature of mode localization. The following results were found when the 'global' systems were mistuned:

1. Behavior for the three levels of mistuning ranged for the different mistuning sets. For the high mistuning level, with green coupling, the mean localization of the modes (as measured by the four/two norm) was seen to range from 0.3800 to 0.8580. This range was 0.5380 to 0.8780 for the intermediate mistuning level and 0.7030 to 0.9050 for the lower mistuning level. For all of the levels of mistuning, it can be seen that both localization and nearly global modes were present. This provides more emphasis on the statistical nature of localization. The degree of localization cannot be determined solely on the statistics of the system mistuning.

2. For all of the system coupling levels, the mean response of the system to the mistuning levels was an increase in localization as disorder was increased. This result was as expected. Due to the number of data points available, it is not possible to derive any

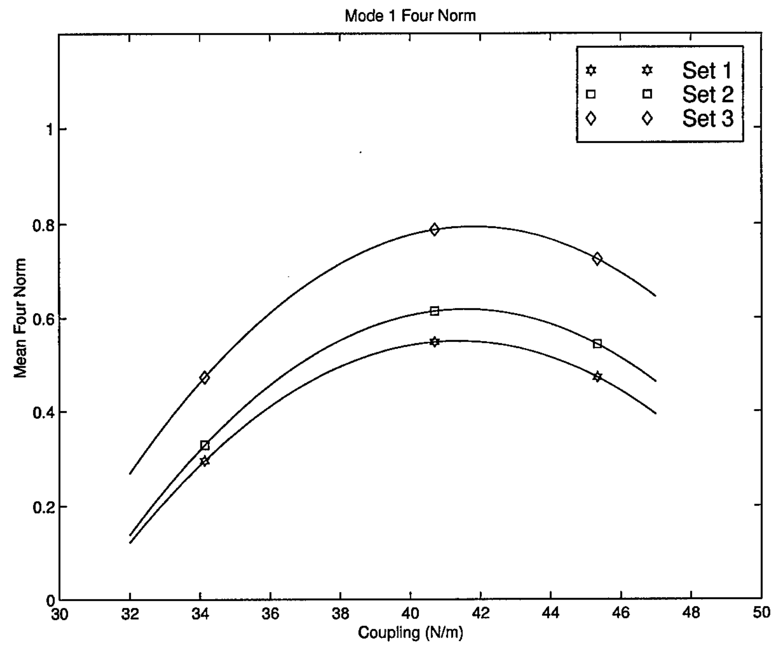


Figure 4.1 Mode One Localization Versus Coupling Level

relationship between the mistuning level and the localization level. All that can be cited is the trend of increasing localization to increasing mistuning that was observed.

3. The modal bandwidth proved to be a good indicator of what ordered system was most likely to localize with the addition of localization. For the three coupling levels considered, orange, yellow and green, the modal bandwidth was found to be highest for the yellow and lowest for the orange. Overall, the yellow coupling level provided the lowest localization level for all of the mistuning levels. This was a surprising result since the green level had a higher level of coupling than the yellow system. This counterintuitive behavior may be due to the higher disorder that was present in the green system when compared to the yellow system. As a result, modal bandwidth may be a better measure, over just system coupling level, when determining what system is most likely to localize. Seen in Figures 4.1 and 4.2 are plots of mode one localization versus coupling and localization versus base system bandwidth. For the region considered, the plot with bandwidth as the independent variable is fairly linear an monotonically increasing. The same cannot be said for the plot with coupling as the independent variable.

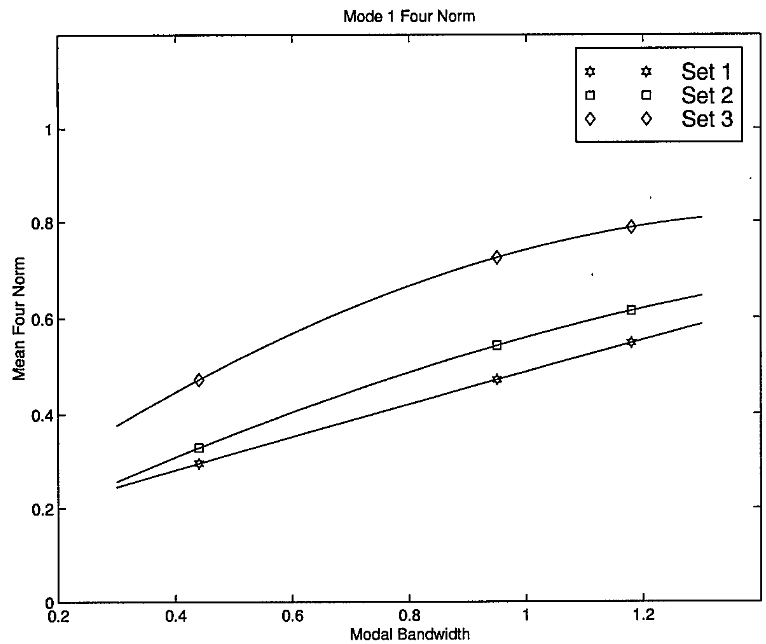


Figure 4.2 Mode One Localization Versus Modal Bandwidth

The bandwidth measurement is able to account for slight mistuning that is present in the system as compared to coupling level alone. Coupling may be a sufficient measure in analytical systems, where all mistuning is easier to quantify. An additional result seen with modal bandwidth was that it increased with increasing mistuning standard deviation.

4. One of the more interesting results seen with the intentional mistuning of the physical system was the 'targeted' mistuning that resulted from mistuning only one of the six array ribs. It was found that addition of mass to one rib targets the first three modes. More specifically, it results in severe localization of the first mode and switching of the second and third modes. The same behavior is seen when mass was removed from a single rib. This resulted in severe localization of the last mode and switching of the fourth and fifth modes. The higher modes appeared more sensitive to the mistuning. For all coupling levels, it was found that the sixth mode experienced more severe localization than the first mode when comparing the targeted localization results for each. This behavior may be due to the increase/decrease seen in the individual rib frequencies by subtraction/addition of mass.

Effectiveness of PZT Coupling. The addition of passive, non-amplified, PZT coupling provided minimal (barely noticeable) reduction of system localization. The PZT coupling ratio present in the system indicates a low efficiency in electromechanical energy transfer. The low value of this factor was manifested in the minimal PZT coupling observed.

Localization Length Scales. Depending on how much data is present, and to what level you are trying to show a trend, the infinity/two norm can be utilized. As was seen with the experimental data, where there was a small amount of data (relative to the numerical experiments), the infinity/two norm indicated the same trends as the four/two norm. However, in the numerical experiment a cut off was seen towards the high levels of localization. The four/two norm showed where the system localization increased to very high levels, where the infinity norm leveled off. This is probably due to the fact that the infinity/two norm is based on only one value of the mode shape deflections and not the whole shape. Even though the infinity/two norm does not indicate high localization well, does it matter how high localization is beyond a specific point? If localization exists beyond a specific threshold, the component under consideration will not be utilized. If indication of localization to a specific threshold is sufficient, the infinity/two norm may be useful.

As for the MAC based scale, at this time it appears ineffective. It provided a significant amount of scatter in the experimental results and indicated excessively severe localization for low levels of mistuning in the numerical experiments. MAC based scales may be worthy of future research, however; the one investigated here proved ineffective.

Comparison of Numerical and Experimental Results. Differences existed between the numerical and experimental results. The numerical results indicated that localization decreased as coupling increased. This result is in contrast to the experimental system that displayed a a decrease followed by an increase. This result is probably due to the fact that the experimental system had a large mistuning introduced in its coupling in addition to the mass mistuning present. As expected, all systems (both of the

numerical and the experimental) indicated an overall increase in system localization as mistuning standard deviation increased.

Another anticipated result was the agreement between the modal behavior of the circulant numerical system and the experimental system. It was found that first and last mode of the first (and only determined) modal band were the most susceptible to localization, with the last mode experiencing the most overall localization.

Recommendations

More Data, More Data, More Data! The effect of coupling on the system mean and mistuning behavior, as shown in Chapter 2, was particularly interesting. To determine the actual relation between the system coupling and this behavior, more coupling level data is required over the range considered, and extension of the range is probably required. With this data a numerical relationship between coupling and this mistuning behavior may be attainable.

It would be of interest to find what level of coupling is required to provide extension of the near linear region of mean localization standard deviation to mistuning standard deviation. In that region, global and further extended systems are still probable. Beyond that region, particularly within the region of decrease beyond it, the probability of localization is increased. It is obvious that increasing the coupling will prolong the near linear region, but since high levels of coupling are not readily available at all times, the transition region between low and high coupling is of interest.

The same need for more data is certainly present for the experimental work that was conducted. More data at each of the mistuning levels, more mistuning levels and more coupling levels would provide a clearer view of the actual behavior beyond the basic trends that were observable.

PZT Coupling. Additional methods of PZT coupling should be investigated. The efficiency of the electromechanical energy transfer can be increased through the introduction of an inductor circuit. Addition of such a circuit can provide amplification of

the PZT to PZT voltage in the frequency region of interest. This may yield a considerable reduction of localization. Also, it may be of interest to study active control of the structure with PZT.

Complex Modes. Complex modes appeared in the experimental results. Although some degree of complexity, an indication of damping, is to be expected in any real system, the levels seen for the localized modes was beyond that to be anticipated for a lightly damped system. Whether this behavior is the actual system behavior or simply an artifact of testing and data processing methods is not known. As stated in Chapter 3, this same behavior has been seen in other mode localization studies [12]. The exact reason for this modal complexity is of interest and should be the focus of future research efforts.

Summary

The purpose of this experiment was to study the statistical behavior of mode localization. Previous research has only considered a limited number of mistuning sets. To see how a system behaves, given a knowledge of the mistuning statistical behavior, more mistuning iterations must be considered. Multiple mistuning sets were considered both numerically and experimentally in this thesis. The localization trends for various coupling and mistuning levels were analyzed and discussed.

In this form, this research does not have a direct application. It adds to the body of knowledge about this phenomena. It is hoped that the findings and the models developed here will aid in improving the understanding of mode localization. With full understanding of localization it may be possible to reduce/eliminate it or use it for beneficial purposes.

Understanding of mode localization and finding a means of controlling it has the potential of enhancing both air and space technologies that impact the Air Force. The capability to eliminate localization in compressor blades would allow for the use of lighter compressor blades. This technology development would significantly impact aircraft range and reliability. Additionally, the capability to control localization has obvious benefits for space technology. Through full understanding and control of mode localization point-

ing requirements and shape control for space antennae can be enhanced beyond current capabilities.

Appendix A. Matlab Code

Monte Carlo Code - Six Open Ended Pendulum System

```
% This program is a monte carlo simulation for a six pendulum system.
% The program analyzes the effects of mode localization for the
% system when mistuning masses are added.  The mistuning masses are
% normally distributed with mean zero and a varying variance.  Part of
% this program is to generate data to show the effects of error
% variance on mode localization.
%
% Additionally this program allows the user to set a rejection criteria
% to simulate real world quality control.
%
% Author: Amy Cox
% ahumphre@afit.af.mil
% Air Force Institute of Technology,ENY

clear


%***********************************************************************
% 1.0 Developing the system - creating the mass and stiffness matrices.
%***********************************************************************

% 1.1 Generating stiffness values
k=zeros(1,11);
kd1=ones(1,6);
% Select coupling stiffness (un-comment desired coupling level)
kd2=0.1*ones(1,6);
%kd2=0.05*ones(1,6);
%kd2=0.3*ones(1,6);
for n=1:6;
   k((2*n)-1)=kd1(n);
   k((2*n))=kd2(n);
end

% 1.2 Generating stiffness matrix
kk=zeros(6,6);
l=1;
% Row 1
kk(1,1)=k(1)+(l*l*k(2));
kk(1,2)=-(l*l*k(2));
% Row 2
```

```
kk(2,1)=kk(1,2);
kk(2,2)=k(3)+(l*l*k(2))+(l*l*k(4));
kk(2,3)=-(l*l*k(4));
% Row 3
kk(3,2)=kk(2,3);
kk(3,3)=k(5)+(l*l*k(4))+(l*l*k(6));
kk(3,4)=-(l*l*k(6));
% Row 4
kk(4,3)=kk(3,4);
kk(4,4)=k(7)+(l*l*k(6))+(l*l*k(8));
kk(4,5)=-(l*l*k(8));
% Row 5
kk(5,4)=kk(4,5);
kk(5,5)=k(9)+(l*l*k(8))+(l*l*k(10));
kk(5,6)=-(l*l*k(10));
% Row 6
kk(6,5)=kk(5,6);
kk(6,6)=k(11)+(l*l*k(10));

% 1.3 Generating mass matrix
m=zeros(6,6);

for n=1:6
      m(n,n)=1;
end

%************************************************************************
% 2.0 Gathering information for the ordered system
%************************************************************************

% 2.1 Base System Eigenvalues and Eigenvectors

[Lambda,Phi,Psi]=eign(kk,m);

xo=Phi;

lamo=Lambda;

% 2.2 Collecting base system information for the four norm/two norm length scale

fouro = ((sum(xo.^2)).^2)./sum(xo.^4);

% 2.3 Collecting base system information for the Infinity norm/two norm length scale

info=sqrt(sum(xo.^2))./(max(abs(xo)));
```

```
%*************************************************************************
% 3.0 Monte Carlo Runs
%*************************************************************************

% 3.1 Obtaining user input

def = {'0', '5', '200', '10000', '5'};
monty_prompts = {'Minimum Variance (%)'; ...
      'Maximum Variance (%)';...
      'Number of Variances'; ...
      'Number of Monte Carlo Runs'; ...
      'Rejection Criteria (%)'};
monty_title = 'Monte Carlo Setup';
lineNo = 1;
monty_box = inputdlg(monty_prompts, monty_title, lineNo, def);

minvar = (1/100)*str2num(char(monty_box(1)));   % Minimum Variance
maxvar = (1/100)*str2num(char(monty_box(2)));   % Maximum Variance
inloop = str2num(char(monty_box(3)));           % Number of variances
outloop = str2num(char(monty_box(4)));          % Number of randomly generated sets
reject = (1/100)*str2num(char(monty_box(5)));   % Error Rejection criteria


% 3.1 Developing the variance vector
%      The vector provides variance from zero to 0.5 (0 to 5% of the mass).
%      The square root of this value is utilized for mathematical reasons.

c=linspace(minvar,maxvar,inloop);
c=sqrt(c);

% 3.2 Creating base matrices for the values to be generated
inf1 = zeros(inloop,outloop);
inf2 = inf1;
inf3 = inf1;
inf4 = inf1;
inf5 = inf1;
inf6 = inf1;

four1 = inf1;
four2 = inf1;
four3 = inf1;
four4 = inf1;
four5 = inf1;
four6 = inf1;

maclen = inf1';
```

```
qc = infl';

% 3.3 Starting the outer loop that alters the mistuning set for the monte
%     carlo simulations.


counto = 0;
counti = 1;

for ii=1:outloop;

counto = 1+counto;
% 3.4 Creating base sets to compare new modes to

        base1 = [xo(:,1) xo(:,1) xo(:,1) xo(:,1) xo(:,1) xo(:,1)];
        base2 = [xo(:,2) xo(:,2) xo(:,2) xo(:,2) xo(:,2) xo(:,2)];
        base3 = [xo(:,3) xo(:,3) xo(:,3) xo(:,3) xo(:,3) xo(:,3)];
        base4 = [xo(:,4) xo(:,4) xo(:,4) xo(:,4) xo(:,4) xo(:,4)];
        base5 = [xo(:,5) xo(:,5) xo(:,5) xo(:,5) xo(:,5) xo(:,5)];
        base6 = [xo(:,6) xo(:,6) xo(:,6) xo(:,6) xo(:,6) xo(:,6)];

% 3.4.1 Generating the random set

delmo = diag(randn(6,1));

% 3.5 Starting the loop that changes the standard deviation/variance of the mistuning set.

for jj=1:inloop;

% 3.6 Generating a mistuning matrix for the mass matrix.
%     Matlabs random number generator randn has been utilized
%     to generate the mistuning matrix values.
%     The new mass matrix will be of the form m+c*delm.

   delm = c(jj)*delmo;
   mm=1*1*(m+delm);

% 3.6.1 Finding if the set generated is withing quality control standards

a = abs(min(diag(delm)));
b=max(diag(delm));
extrm = [a(1) b(1)];
extrm = max(extrm);
if extrm >= reject
   qc(ii,jj)=0; % Zero indicates a point beyond rejection standards
```

```
else
   qc(ii,jj)=1; % One indicates an acceptable mistuning set
end

% 3.6.2 Determining the mean and standard deviation of each mistuning set

mismean(ii,jj) = mean(diag(delm));
missd(ii,jj) = sqrt(mean((diag(delm)).^2));

% 3.6.3 Determining the infinity norm of each mistuning set

dum = max(abs(delm));
dum = dum(1,1);
dum = find(abs(delm) == dum);
dum = dum(1,1);
misinf(ii,jj) = delm(dum);

% 3.6.4 Determining the two norm of each mistuning set

mistwo(ii,jj) = sqrt(sum((diag(delm)).^2));

% 3.6.5 Determining the four norm of each mistuning set

misfour(ii,jj) = (sum((diag(delm)).^4)).^(1/4);

% 3.7 Finding the eigenvalues and eigenvectors for the mistuned systems

   [Lambda,Phi,Psi]=eign(kk,mm);

% 3.8 Sorting the modes so that mode flipping does not occur

% 3.8.1 Determining the difference between the calculated modes and
%       the base modes.

   del1 = [Phi-base1 Phi+base1];
   del2 = [Phi-base2 Phi+base2];
   del3 = [Phi-base3 Phi+base3];
   del4 = [Phi-base4 Phi+base4];
   del5 = [Phi-base5 Phi+base5];
   del6 = [Phi-base6 Phi+base6];

% 3.8.2 Genenerating two matrices that have all of the possible values
%       for the eigenvalues and eigenvectors.

   big_phi = [Phi -Phi];
   big_lambda = [Lambda.' Lambda.'];
```

```
% 3.8.3 Determining the norms for the individual columns of the six difference matrices

        for aa = 1:12
        nrm(1,aa) = sum(abs(del1(:,aa)));
        nrm(2,aa) = sum(abs(del2(:,aa)));
        nrm(3,aa) = sum(abs(del3(:,aa)));
        nrm(4,aa) = sum(abs(del4(:,aa)));
        nrm(5,aa) = sum(abs(del5(:,aa)));
        nrm(6,aa) = sum(abs(del6(:,aa)));
        end

% 3.8.4 Finding the least differences to determine which calculated mode
%      goes with which base mode.

    [junk,pos(1)] = min(nrm(1,:));
    [junk,pos(2)] = min(nrm(2,:));
    [junk,pos(3)] = min(nrm(3,:));
    [junk,pos(4)] = min(nrm(4,:));
    [junk,pos(5)] = min(nrm(5,:));
    [junk,pos(6)] = min(nrm(6,:));

% 3.8.5 Assigning the individual mode shapes to there matrices

    x = big_phi(:,pos);

% 3.8.6 Reassinging the base set for the next run

    base1 = [x(:,1) x(:,1) x(:,1) x(:,1) x(:,1) x(:,1)];
    base2 = [x(:,2) x(:,2) x(:,2) x(:,2) x(:,2) x(:,2)];
    base3 = [x(:,3) x(:,3) x(:,3) x(:,3) x(:,3) x(:,3)];
    base4 = [x(:,4) x(:,4) x(:,4) x(:,4) x(:,4) x(:,4)];
    base5 = [x(:,5) x(:,5) x(:,5) x(:,5) x(:,5) x(:,5)];
    base6 = [x(:,6) x(:,6) x(:,6) x(:,6) x(:,6) x(:,6)];


% 3.9.0 Calculating length scales for the disordered system

% 3.9.1 Calculating Infinity Norm/Two Norm Length Scale

    infall = (sqrt(sum(x.^2))./(max(abs(x)))./info;
    inf1(jj,ii)=infall(1);
    inf2(jj,ii)=infall(2);
    inf3(jj,ii)=infall(3);
    inf4(jj,ii)=infall(4);
    inf5(jj,ii)=infall(5);
```

```
   inf6(jj,ii)=infall(6);

% 3.9.2 Calculating the four/two norm length scale

   fourall = (((sum(x.^2)).^2)./sum(x.^4))./fouro;
   four1(jj,ii)=fourall(1);
   four2(jj,ii)=fourall(2);
   four3(jj,ii)=fourall(3);
   four4(jj,ii)=fourall(4);
   four5(jj,ii)=fourall(5);
   four6(jj,ii)=fourall(6);

% 3.9.3 Calculating the modal assurance criteria length scale
   mac = (((((x')*xo).^2))./((diag((x')*(x)).*diag((xo')*(xo)))*ones(1,6))).';
   maclen(ii,jj) = 1/cond(mac);

end

% 3.10.0 Loop Counter so it is known how far the program has gone
if counto == 500
      counto = 0;
      X = ['Loop Number: ', num2str(counti)];% Output the loop number to the screen
      disp(X)
      time = clock; % Output the month day hour minute and second to the screen
      Y = ['Month: ',num2str(time(1,2)),', Day: ',num2str(time(1,3)),', Hour: ',...
      num2str(time(1,4)),', Minute: ',num2str(time(1,5)),' & Second: ',num2str(time(1,6))];
      disp(Y)
      counti = counti + 1;
      end
end

%***************************************************************************
% 4.0 Determining the histogram information for each length scale
%***************************************************************************

% 4.1 Setting the bin locations
X = [0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95 1.05 1.15 1.25 1.35 1.45];
XM = [0.015 0.035 0.055 0.075 0.095 0.115 0.135 0.155 0.175 0.195 ...
      0.215 0.235 0.255 0.275 0.295 0.315 0.335 0.355 0.375 0.395 ...
      0.415 0.435 0.455 0.475 0.495 0.515 0.535 0.555 0.575 0.595 ...
      0.615 0.635 0.655 0.675 0.695 0.715 0.735 0.755 0.775 0.795 ...
      0.815 0.835 0.855 0.875 0.895 0.915 0.935 0.955 0.975 0.995];

% 4.2 Determining bin frequencies for the infinity norm
[n1]=hist(inf1',X);
[n2]=hist(inf2',X);
```

```
[n3]=hist(inf3',X);
[n4]=hist(inf4',X);
[n5]=hist(inf5',X);
[n6]=hist(inf6',X);

% 4.3 Determining bin frequencies for the four norm
[m1]=hist(four1',X);
[m2]=hist(four2',X);
[m3]=hist(four3',X);
[m4]=hist(four4',X);
[m5]=hist(four5',X);
[m6]=hist(four6',X);

% 4.4 Determining bin frequencies for the mac scales
[o]=hist(maclen,XM);


%*************************************************************************
% 5.0 Plotting the results
%*************************************************************************

% 5.1 Squaring the variance to rectify changes made to it in step 3.1
c = c.*c;

% 5.2 Plotting the infinity norm results

figure(1)
surf(c,X,n1*100/ii)
title('Mode 1')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(2)
surf(c,X,n2*100/ii)
title('Mode 2')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(3)
surf(c,X,n3*100/ii)
title('Mode 3')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')
```

```
figure(4)
surf(c,X,n4*100/ii)
title('Mode 4')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(5)
surf(c,X,n5*100/ii)
title('Mode 5')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(6)
surf(c,X,n6*100/ii)
title('Mode 6')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

% 5.3 Plotting the four norm results

figure(7)
surf(c,X,m1*100/ii)
title('Mode 1')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(8)
surf(c,X,m2*100/ii)
title('Mode 2')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(9)
surf(c,X,m3*100/ii)
title('Mode 3')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(10)
```

```
surf(c,X,m4*100/ii)
title('Mode 4')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(11)
surf(c,X,m5*100/ii)
title('Mode 5')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(12)
surf(c,X,m6*100/ii)
title('Mode 6')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

% 5.4 Plotting the mac results

figure(13)
surf(c,XM,o*100/ii)
title('Modal Band 1')
xlabel('Variance')
ylabel('MAC Length Scale')
zlabel('Probability')
```

Monte Carlo Code - Six Closed Ended Pendulum System

```
% This program is a monte carlo simulation for a six pendulum system.
% The pendulum system is connected at both ends and therefor circulant.
% The program analyzes the effects of mode localization for the
% system when mistuning masses are added.  The mistuning masses are
% normally distributed with mean zero and a varying variance.  Part of
% this program is to generate data to show the effects of error
% variance on mode localization.
%
% Additionally this program allows the user to set a rejection criteria
% to simulate real world quality control.
%
% Author: Amy Cox
% ahumphre@afit.af.mil
% Air Force Institute of Technology,ENY

clear

%*********************************************************************
% 1.0 Developing the system - creating the mass and stiffness matrices.
%*********************************************************************

% 1.1 Generating stiffness values
k=zeros(1,11);
kd1=ones(1,6);
% Select coupling stiffness (un-comment desired coupling level)
kd2=0.1*ones(1,6);
%kd2=0.05*ones(1,6);
%kd2=0.3*ones(1,6);
for n=1:6;
   k((2*n)-1)=kd1(n);
   k((2*n))=kd2(n);
end

% 1.2 Generating stiffness matrix
kk=zeros(6,6);
l=1;
% Row 1
        kk(1,1)=k(1)+(l*l*(3/4)*(k(2)+k(12)));
        kk(1,2)=-((3/4)*l*l*k(2));
        kk(1,6)=-((3/4)*l*l*k(12));
% Row 2
        kk(2,1)=kk(1,2);
        kk(2,2)=k(3)+(l*l*(3/4)*(k(4)+k(2)));
        kk(2,3)=-((3/4)*l*l*k(4));
```

```
% Row 3
        kk(3,2)=kk(2,3);
        kk(3,3)=k(5)+(1*1*(3/4)*(k(6)+k(4)));
        kk(3,4)=-((3/4)*1*1*k(6));
% Row 4
        kk(4,3)=kk(3,4);
        kk(4,4)=k(7)+(1*1*(3/4)*(k(8)+k(6)));
        kk(4,5)=-((3/4)*1*1*k(8));
% Row 5
        kk(5,4)=kk(4,5);
        kk(5,5)=k(9)+(1*1*(3/4)*(k(10)+k(8)));
        kk(5,6)=-((3/4)*1*1*k(10));
% Row 6
        kk(6,1)=kk(1,6);
        kk(6,5)=kk(5,6);
        kk(6,6)=k(11)+(1*1*(3/4)*(k(12)+k(10)));

% 1.3 Generating mass matrix
m=zeros(6,6);

for n=1:6
      m(n,n)=1;
end

%************************************************************************
% 2.0 Gathering information for the ordered system
%************************************************************************

% 2.1 Base System Eigenvalues and Eigenvectors

[Lambda,Phi,Psi]=eign(kk,m);

xo=Phi;

lamo=Lambda;

% 2.2 Collecting base system information for the four norm/two norm length scale

fouro = ((sum(xo.^2)).^2)./sum(xo.^4);

% 2.3 Collecting base system information for the Infinity norm/two norm length scale

info=sqrt(sum(xo.^2))./(max(abs(xo)));

%************************************************************************
% 3.0 Monte Carlo Runs
```

```
%**************************************************************************

% 3.1 Obtaining user input

def = {'0', '5', '200', '10000', '5'};
monty_prompts = {'Minimum Variance (%)'; ...
      'Maximum Variance (%)';...
      'Number of Variances'; ...
      'Number of Monte Carlo Runs'; ...
      'Rejection Criteria (%)'};
monty_title = 'Monte Carlo Setup';
lineNo = 1;
monty_box = inputdlg(monty_prompts, monty_title, lineNo, def);

minvar = (1/100)*str2num(char(monty_box(1)));   % Minimum Variance
maxvar = (1/100)*str2num(char(monty_box(2)));   % Maximum Variance
inloop = str2num(char(monty_box(3)));           % Number of variances
outloop = str2num(char(monty_box(4)));          % Number of randomly generated sets
reject = (1/100)*str2num(char(monty_box(5)));   % Error Rejection criteria


% 3.1 Developing the variance vector
%     The vector provides variance from zero to 0.5 (0 to 5% of the mass).
%     The square root of this value is utilized for mathematical reasons.

c=linspace(minvar,maxvar,inloop);
c=sqrt(c);

% 3.2 Creating base matrices for the values to be generated
inf1 = zeros(inloop,outloop);
inf2 = inf1;
inf3 = inf1;
inf4 = inf1;
inf5 = inf1;
inf6 = inf1;

four1 = inf1;
four2 = inf1;
four3 = inf1;
four4 = inf1;
four5 = inf1;
four6 = inf1;

maclen = inf1';

qc = inf1';
```

```
% 3.3 Starting the outer loop that alters the mistuning set for the monte
%     carlo simulations.


counto = 0;
counti = 1;

for ii=1:outloop;

counto = 1+counto;
% 3.4 Creating base sets to compare new modes to

        base1 = [xo(:,1) xo(:,1) xo(:,1) xo(:,1) xo(:,1) xo(:,1)];
        base2 = [xo(:,2) xo(:,2) xo(:,2) xo(:,2) xo(:,2) xo(:,2)];
        base3 = [xo(:,3) xo(:,3) xo(:,3) xo(:,3) xo(:,3) xo(:,3)];
        base4 = [xo(:,4) xo(:,4) xo(:,4) xo(:,4) xo(:,4) xo(:,4)];
        base5 = [xo(:,5) xo(:,5) xo(:,5) xo(:,5) xo(:,5) xo(:,5)];
        base6 = [xo(:,6) xo(:,6) xo(:,6) xo(:,6) xo(:,6) xo(:,6)];

% 3.4.1 Generating the random set

delmo = diag(randn(6,1));

% 3.5 Starting the loop that changes the standard deviation/variance of the mistuning set.

for jj=1:inloop;

% 3.6 Generating a mistuning matrix for the mass matrix.
%     Matlabs random number generator randn has been utilized
%     to generate the mistuning matrix values.
%     The new mass matrix will be of the form m+c*delm.

   delm = c(jj)*delmo;
   mm=1*1*(m+delm);

% 3.6.1 Finding if the set generated is withing quality control standards

a = abs(min(diag(delm)));
b=max(diag(delm));
extrm = [a(1) b(1)];
extrm = max(extrm);
if extrm >= reject
   qc(ii,jj)=0; % Zero indicates a point beyond rejection standards
else
   qc(ii,jj)=1; % One indicates an acceptable mistuning set
```

```
end

% 3.6.2 Determining the mean and standard deviation of each mistuning set

mismean(ii,jj) = mean(diag(delm));
missd(ii,jj) = sqrt(mean((diag(delm)).^2));

% 3.6.3 Determining the infinity norm of each mistuning set

dum = max(abs(delm));
dum = dum(1,1);
dum = find(abs(delm) == dum);
dum = dum(1,1);
misinf(ii,jj) = delm(dum);

% 3.6.4 Determining the two norm of each mistuning set

mistwo(ii,jj) = sqrt(sum((diag(delm)).^2));

% 3.6.5 Determining the four norm of each mistuning set

misfour(ii,jj) = (sum((diag(delm)).^4)).^(1/4);

% 3.7 Finding the eigenvalues and eigenvectors for the mistuned systems

   [Lambda,Phi,Psi]=eign(kk,mm);

% 3.8 Sorting the modes so that mode flipping does not occur

% 3.8.1 Determining the difference between the calculated modes and
%       the base modes.

   del1 = [Phi-base1 Phi+base1];
   del2 = [Phi-base2 Phi+base2];
   del3 = [Phi-base3 Phi+base3];
   del4 = [Phi-base4 Phi+base4];
   del5 = [Phi-base5 Phi+base5];
   del6 = [Phi-base6 Phi+base6];

% 3.8.2 Genenerating two matrices that have all of the possible values
%       for the eigenvalues and eigenvectors.

   big_phi = [Phi -Phi];
   big_lambda = [Lambda.' Lambda.'];

% 3.8.3 Determining the norms for the individual columns of the six difference matrices
```

```
        for aa = 1:12
        nrm(1,aa) = sum(abs(del1(:,aa)));
        nrm(2,aa) = sum(abs(del2(:,aa)));
        nrm(3,aa) = sum(abs(del3(:,aa)));
        nrm(4,aa) = sum(abs(del4(:,aa)));
        nrm(5,aa) = sum(abs(del5(:,aa)));
        nrm(6,aa) = sum(abs(del6(:,aa)));
        end

% 3.8.4 Finding the least differences to determine which calculated mode
%       goes with which base mode.

   [junk,pos(1)] = min(nrm(1,:));
   [junk,pos(2)] = min(nrm(2,:));
   [junk,pos(3)] = min(nrm(3,:));
   [junk,pos(4)] = min(nrm(4,:));
   [junk,pos(5)] = min(nrm(5,:));
   [junk,pos(6)] = min(nrm(6,:));

% 3.8.5 Assigning the individual mode shapes to there matrices

   x = big_phi(:,pos);

% 3.8.6 Reassinging the base set for the next run

   base1 = [x(:,1) x(:,1) x(:,1) x(:,1) x(:,1) x(:,1)];
   base2 = [x(:,2) x(:,2) x(:,2) x(:,2) x(:,2) x(:,2)];
   base3 = [x(:,3) x(:,3) x(:,3) x(:,3) x(:,3) x(:,3)];
   base4 = [x(:,4) x(:,4) x(:,4) x(:,4) x(:,4) x(:,4)];
   base5 = [x(:,5) x(:,5) x(:,5) x(:,5) x(:,5) x(:,5)];
   base6 = [x(:,6) x(:,6) x(:,6) x(:,6) x(:,6) x(:,6)];


% 3.9.0 Calculating length scales for the disordered system

% 3.9.1 Calculating Infinity Norm/Two Norm Length Scale

   infall = (sqrt(sum(x.^2))./(max(abs(x)))./info;
   inf1(jj,ii)=infall(1);
   inf2(jj,ii)=infall(2);
   inf3(jj,ii)=infall(3);
   inf4(jj,ii)=infall(4);
   inf5(jj,ii)=infall(5);
   inf6(jj,ii)=infall(6);
```

```
% 3.9.2 Calculating the four/two norm length scale

   fourall = (((sum(x.^2)).^2)./sum(x.^4))./fouro;
   four1(jj,ii)=fourall(1);
   four2(jj,ii)=fourall(2);
   four3(jj,ii)=fourall(3);
   four4(jj,ii)=fourall(4);
   four5(jj,ii)=fourall(5);
   four6(jj,ii)=fourall(6);

% 3.9.3 Calculating the modal assurance criteria length scale
   mac = (((((x')*xo).^2))./((diag((x')*(x)).*diag((xo')*(xo)))*ones(1,6))).';
   maclen(ii,jj) = 1/cond(mac);

end

% 3.10.0 Loop Counter so it is known how far the program has gone
if counto == 500
      counto = 0;
      X = ['Loop Number: ', num2str(counti)];% Output the loop number to the screen
      disp(X)
      time = clock; % Output the month day hour minute and second to the screen
      Y = ['Month: ',num2str(time(1,2)),', Day: ',num2str(time(1,3)),', Hour: ',...
      num2str(time(1,4)),', Minute: ',num2str(time(1,5)),' & Second: ',num2str(time(1,6))];
      disp(Y)
      counti = counti + 1;
      end
end

%*************************************************************************
% 4.0 Determining the histogram information for each length scale
%*************************************************************************

% 4.1 Setting the bin locations
X = [0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95 1.05 1.15 1.25 1.35 1.45];
XM = [0.015 0.035 0.055 0.075 0.095 0.115 0.135 0.155 0.175 0.195 ...
      0.215 0.235 0.255 0.275 0.295 0.315 0.335 0.355 0.375 0.395 ...
      0.415 0.435 0.455 0.475 0.495 0.515 0.535 0.555 0.575 0.595 ...
      0.615 0.635 0.655 0.675 0.695 0.715 0.735 0.755 0.775 0.795 ...
      0.815 0.835 0.855 0.875 0.895 0.915 0.935 0.955 0.975 0.995];

% 4.2 Determining bin frequencies for the infinity norm
[n1]=hist(inf1',X);
[n2]=hist(inf2',X);
[n3]=hist(inf3',X);
[n4]=hist(inf4',X);
```

```
[n5]=hist(inf5',X);
[n6]=hist(inf6',X);

% 4.3 Determining bin frequencies for the four norm
[m1]=hist(four1',X);
[m2]=hist(four2',X);
[m3]=hist(four3',X);
[m4]=hist(four4',X);
[m5]=hist(four5',X);
[m6]=hist(four6',X);

% 4.4 Determining bin frequencies for the mac scales
[o]=hist(maclen,XM);


%*************************************************************************
% 5.0 Plotting the results
%*************************************************************************

% 5.1 Squaring the variance to rectify changes made to it in step 3.1
c = c.*c;

% 5.2 Plotting the infinity norm results

figure(1)
surf(c,X,n1*100/ii)
title('Mode 1')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(2)
surf(c,X,n2*100/ii)
title('Mode 2')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(3)
surf(c,X,n3*100/ii)
title('Mode 3')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(4)
```

```
surf(c,X,n4*100/ii)
title('Mode 4')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(5)
surf(c,X,n5*100/ii)
title('Mode 5')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

figure(6)
surf(c,X,n6*100/ii)
title('Mode 6')
xlabel('Variance')
ylabel('Infinity/Two Norm Length Scale')
zlabel('Probability')

% 5.3 Plotting the four norm results

figure(7)
surf(c,X,m1*100/ii)
title('Mode 1')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(8)
surf(c,X,m2*100/ii)
title('Mode 2')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(9)
surf(c,X,m3*100/ii)
title('Mode 3')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(10)
surf(c,X,m4*100/ii)
title('Mode 4')
```

```
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(11)
surf(c,X,m5*100/ii)
title('Mode 5')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

figure(12)
surf(c,X,m6*100/ii)
title('Mode 6')
xlabel('Variance')
ylabel('Four/Two Norm Length Scale')
zlabel('Probability')

% 5.4 Plotting the mac results

figure(13)
surf(c,XM,o*100/ii)
title('Modal Band 1')
xlabel('Variance')
ylabel('MAC Length Scale')
zlabel('Probability')
```

Datascope Calibration Algorithm

```
% This program is the callback for the calibration call in the Datascope
% Run menu. The following calculates the sensitivity of an accelerometer
% through comparison calibration. The following code utilizes overlap
% processing, averaging and hanning windows.

% 1.0 Clearing old data that may effect analysis
clear true test h hv gxx gxf gff gfx coher x

% 2.0 Loading Defaults inputs
load cb_caldata

% 3.0 Obtain user input for calibration
calibration_prompts = {'Enter the number of averages'; ...
      'Enter the Overlap Value';...
      'What is the sensitivity of the true accelerometer?'; ...
      'Enter the calibration blocksize'; ...
      'Enter channel of standard accelerometer'; ...
      'Enter channel of test accelerometer'};
calibration_title = 'Calibration setup';
lineNo = 1;
calibration_box = inputdlg(calibration_prompts,...
calibration_title, lineNo, def);

a=str2num(char(calibration_box(1)));         % Number of averages
ol=str2num(char(calibration_box(2)));        % Percent overlap
sentrue=str2num(char(calibration_box(3))); % Sensitivity of true accel
bs = str2num(char(calibration_box(4)));      % Calibration blocksize (separate from datascope)
channel_standard = str2num(char(calibration_box(5))); % Standard Accel Channel
channel_test = str2num(char(calibration_box(6)));     % Test Accel Channel

% 3.1 Resetting default values and saving them to a file
def ={num2str(a),num2str(ol),num2str(sentrue),num2str(bs),...
num2str(channel_standard),num2str(channel_test)};
save cb_caldata def


olap=ol/100;                   % Percent overlap (in decimal form)
olp = floor(olap*bs);          % Number of overlap points
tad = a * bs - (a-1) * olp;  % Total amount of data points

% 3.2 Extracting the data to be utilized
x(:,1)=DATA_MAT_1(8*BLOCKSIZE - tad+1:8*BLOCKSIZE,channel_standard);
x(:,2)=DATA_MAT_1(8*BLOCKSIZE - tad+1:8*BLOCKSIZE,channel_test);
```

```
% 4.0 Determining the rms of the true accel
exrms=x(:,1)/sentrue;
nn=max(size(exrms));
exrms=sqrt(sum(exrms.*exrms/nn));

% 5.0 Creating the hanning window
h=hanning(bs);

% 6.0 Seperating out the input and output blocks and multiplying by
% the hanning window.

% NOTE:  The reason overlap processing is being utilized is to rescue
% the data lost by using the hanning window.  The hanning window chops
% off data at the ends of the window, by doing the overlap this data is
% made use of.
% Due to the overlap processing there are (2*a)-1 data blocks that will
% be created.

c=1;
d=bs;

for ii=1:a
   true(ii,:)=(x(c:d,1).*h)';
   test(ii,:)=(x(c:d,2).*h)';
   c=c+bs-olp;
   d=d+bs-olp;
end

clear x; % Clearing x since it is no longer needed
clear h; % ditto for h

% 7.0 Finding the fft of the true and test data

true=(2/bs)*fft(true);
test=(2/bs)*fft(test);

% 8.0 Obtaining the autopower spectrums (gxx and gff) for the inputs
% and outputs, the cross power spectrums (gxf and gff) and the
% frequency response function (h) between the true and test
% accelerometers.

% 8.1 Seeding the vectors
gxx=zeros(1,bs);
h=gxx;
gfx=gxx;
```

```
gxf=gxx;
gff=gxx;

for ii=1:a
   gxx=gxx+(test(ii,:).*conj(test(ii,:)));
   gxf=gxf+(test(ii,:).*conj(true(ii,:)));
   gfx=gfx+(true(ii,:).*conj(test(ii,:)));
   gff=gff+(true(ii,:).*conj(true(ii,:)));
   h=h+(test(ii,:)./true(ii,:));

end

% 8.2 Dividing by the number of blocks (the above values are the sums,
% to get the average you need to divide by the number of blocks).

gxx=gxx/a;
gxf=gxf/a;
gfx=gfx/a;
gff=gff/a;
h=h/a;

% 9.0 Finding the FRF
% NOTE: The Hv estimator is being utilized to find the FRF since it
% accounts for both error on the input and output.  The Hv
% algorithm performs well in reduction of magnitude errors of the
% frf being determined and not so well for reduction of phase errors.
% Since comparison calibration is utilized, one accel on top of the
% other, a capability to reduce phase error is not necessary, however,
% magnitude error is of utmost importance.
% ***************************************************************
% Hv Equation
% [GFFX]=[GFF  GXF;GXFh GXX] (Where h denotes hermetian)
% [GFFX]=[V][lambda][Vh]
% [V (lambda min)]=[Hv ; -1];

for ii=1:bs
   A=-(gff(ii)+gxx(ii));
   B=(gff(ii)*gxx(ii))-((real(gxf(ii)))^2)-((imag(gxf(ii)))^2);
   lam(1)=((-A)+(sqrt((A*A)-(4*B))))/2;
   lam(2)=((-A)-(sqrt((A*A)-(4*B))))/2;
   dum=lam;
   x=find(dum==min(dum));
   lambda(ii)=lam(x(1));
   hv(ii)=(gxx(ii)-lambda(ii))/gxf(ii);
end
```

```
% 9.1 The FRF needs to be scaled by the sensitivity of the true accel
% to determine the sensitivity of the test accel
hv=hv*sentrue;

% 10.0 Finding the coherence
coher=(gxf.*gfx)./(gxx.*gff);

% 11.0 The frequency vector is the length of the block size with a maximum
% It is scaled by the sampling frequency
f=0:bs-1;
f=f/(bs);
f=f*SPAN*2.56;

% 12.0 Finding the value of the frequency response when the frequency is
% (or is near to) 100hz
dum=find(f==100);
f100=f(dum(1));
hv100=hv(dum(1));

dev=100*(abs(hv)-abs(hv100))/abs(hv100);
dum=ones(1,bs);
hv100=abs(hv100);
dum=dum*hv100;

% 13.0 Finding the minimum and maximum percent deviations
fSPAN = find(f==SPAN);
maxdev=max(abs(dev(1:fSPAN)));
maxdev = find(abs(dev)==maxdev);
fmaxdev = f(maxdev);
maxdev = dev(maxdev);

fSPAN100 = find(f==100);
mindev(1)=min(abs(dev(1:fSPAN100-1)));
mindev(2)=min(abs(dev(fSPAN100+1:fSPAN)));
mindev = min(mindev);
mindev = find(abs(dev)==mindev);
fmindev = f(mindev);
mindev = dev(mindev);

% 14.0 Plotting the results
figure(2)
  subplot(2,1,1)
    plot(f(1:floor(bs/2)),20*log10(abs(hv(1:floor(bs/2)))),f(1:floor(bs/2)),...
    20*log10(dum(1:floor(bs/2))),':')
    title('Frequency Dependant Test Accelerometer Sensitivity')
    xlabel('Frequency (hz)')
```

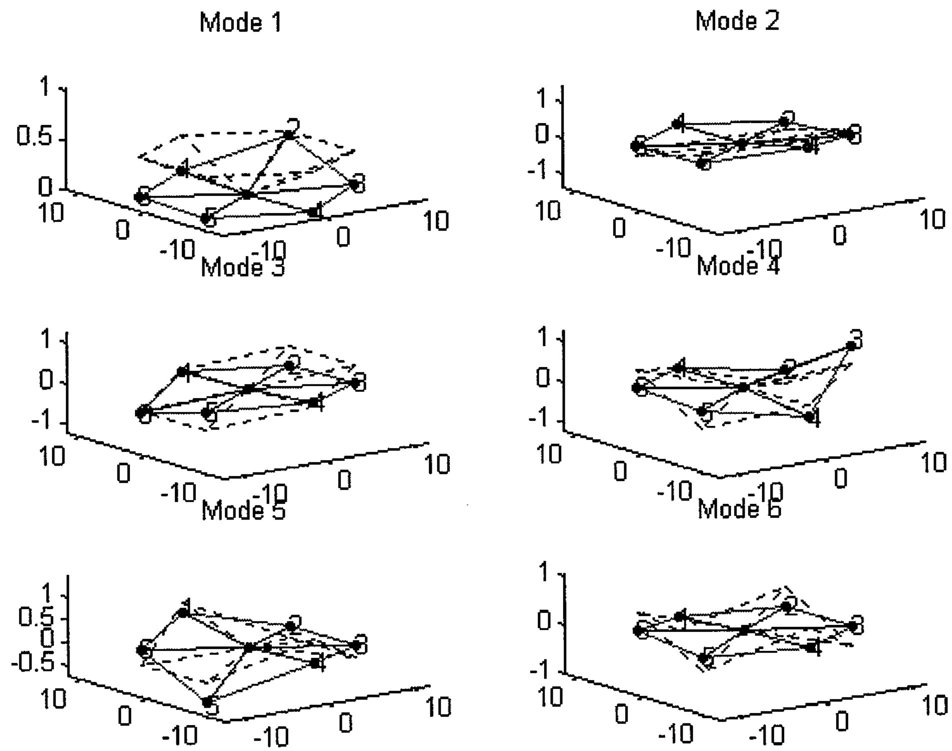
```
    ylabel('Sensitivity (dB)')
    axis([0 f(floor(bs/2)) 20*log10(hv100)-3 20*log10(hv100)+3])
    legend('Frequency Dependant Sensitivity',['Sensitivity at 100Hz: ',...
    num2str(hv100*1000),' mV/g'])

  subplot(2,1,2)
    plot(f(1:floor(bs/2)),(180/pi)*angle(hv(1:floor(bs/2))))
    xlabel('Frequency (hz)')
    ylabel('Phase (degrees)')
    axis([0 f(floor(bs/2)) -180 180])

figure(3)
plot(f(1:floor(bs/2)),coher(1:floor(bs/2)))
xlabel('Frequency (hz)')
ylabel('Coherence')
title('Coherence Between Test and True Accelerometers')
axis([0 f(floor(bs/2)) 0 1])

figure(4)
plot(f(1:floor(bs/2)),dev(1:floor(bs/2)))
xlabel('Frequency (hz)')
ylabel('Deviation (%)')
title('Frequency Response')

% 15.0 Finding the rms value
rmsh = abs(hv).*abs(hv);
rmsh = rmsh/max(size(hv));
rmsh = sum(rmsh);
rmsh = sqrt(rmsh);

% 16.0 Determining values of sensitivity at various frequencies

ff=[5 10 15 30 50 100 300 500 1000];
for n=1:9
   val=find(f>=ff(n));
        fval(n)=f(val(1));
        hval(n)=hv(val(1));
end

hval=abs(hval);

% 17.0 Finding the percent deviation in sensitivity at the various frequency values

perdev=(hval-hval(6))*100/hval(6);

% 18.0 Outputing values to the screen
```

rmsh
fval
perdev
fmaxdev
maxdev
fmindev
mindev

Appendix B. Individual Mistuning Run Results

Included in the following pages are the results for each of the mistuning runs. Each page contains the information for an individual run. The information included is:

1. A graphical representation of each mistuned mode shape (solid line) plotted with its' respective global mode shape (dashed line)
2. A numerical representation of each mode shape
3. Modal frequency and damping
4. The MAC for each mode
5. The modal density
6. The MAC scale
7. The infinity/two and four/two norms for each mode
8. System information (coupling and mistuning set)
9. Data acquisition information
10. Data analysis information



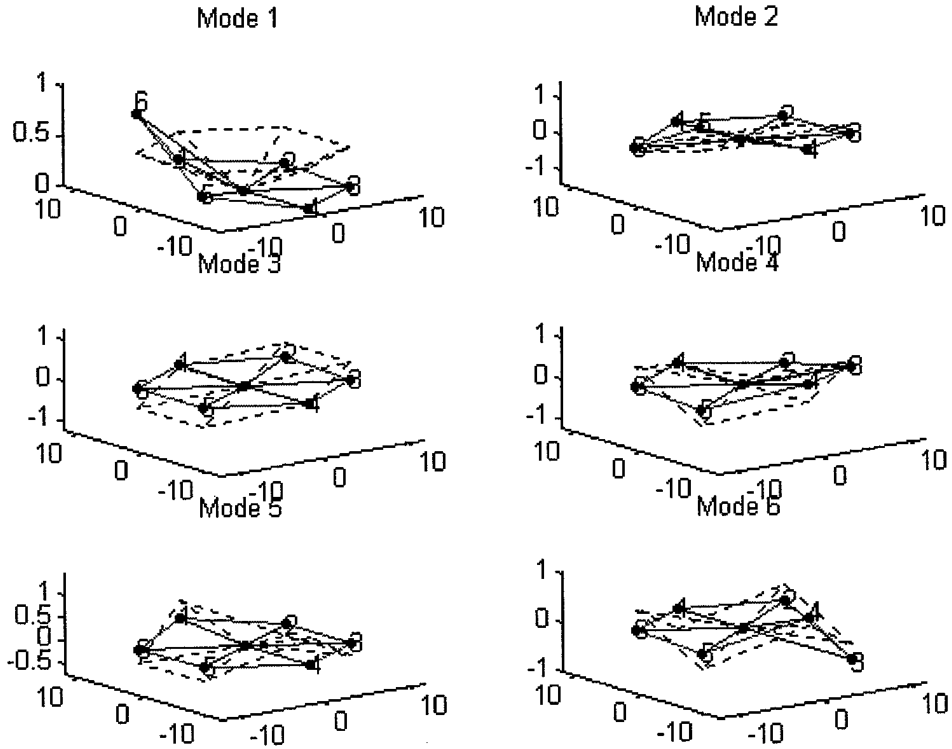
Mode 1	Mode2	Mode 3
0.0030 - 0.0060i	-0.0002 - 0.0002i	-0.0047 - 0.0078i
0.0200 - 0.0479i	-0.0024 + 0.0041i	0.0000 + 0.0011i
0.0033 - 0.0086i	0.0059 - 0.0113i	0.0029 + 0.0039i
0.0013 - 0.0028i	0.0204 - 0.0428i	0.0072 + 0.0111i
0.0001 - 0.0008i	0.0036 - 0.0088i	-0.0038 - 0.0058i
0.0008 - 0.0016i	-0.0005 - 0.0081i	-0.0311 - 0.0491i
Mode 4	**Mode 5**	**Mode 6**
-0.0017 - 0.0002i	0.0258 + 0.0230i	-0.0084 + 0.0526i
-0.0092 - 0.0008i	-0.0018 - 0.0015i	0.0007 - 0.0040i
0.0610 + 0.0064i	-0.0007 - 0.0005i	0.0000 + 0.0010i
-0.0190 - 0.0019i	0.0056 + 0.0043i	0.0009 - 0.0037i
-0.0047 - 0.0006i	-0.0490 - 0.0368i	-0.0074 + 0.0313i
0.0026 - 0.0002i	0.0020 + 0.0013i	0.0021 - 0.0095i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 1

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.7116	0.3385	87.8394	0.4190	0.1846	0.0950
2	10.9433	0.2796	83.7155	0.6195	0.3289	**Modal Density**
3	11.1553	0.5101	90.9522	0.5240	0.3005	1.3386
4	12.3788	0.4030	94.9427	0.5312	0.3153	**File Name**
5	14.7013	0.2205	90.9192	0.6668	0.4040	analy_orange_1
6	14.8515	0.4190	94.7454	0.4848	0.2921	



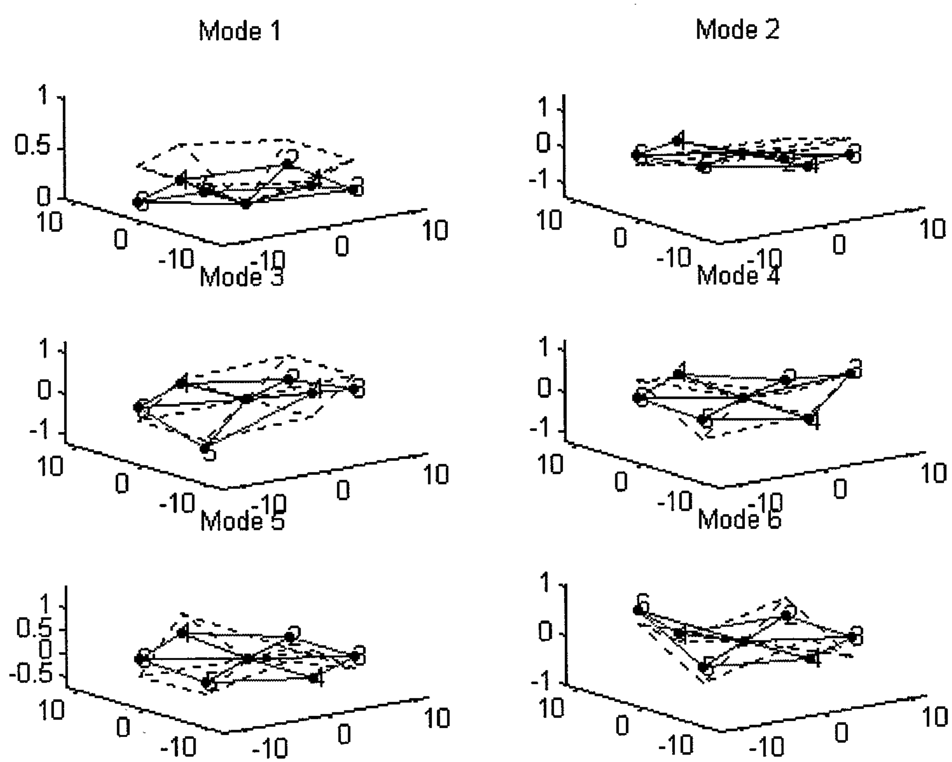
Mode 1	Mode2	Mode 3
0.0056 - 0.0045i	-0.0044 - 0.0009i	0.0033 - 0.0117i
0.0023 - 0.0011i	0.0004 + 0.0002i	0.0104 - 0.0601i
0.0005 - 0.0003i	0.0033 + 0.0006i	0.0018 - 0.0090i
0.0011 - 0.0006i	0.0184 + 0.0032i	0.0005 - 0.0013i
0.0078 - 0.0045i	0.0748 + 0.0120i	0.0000 + 0.0010i
0.0377 - 0.0246i	-0.0115 - 0.0018i	-0.0011 + 0.0044i
Mode 4	**Mode 5**	**Mode 6**
0.0014 - 0.0026i	0.0188 - 0.0906i	-0.0002 - 0.0003i
-0.0042 + 0.0058i	-0.0032 + 0.0165i	0.0044 + 0.0018i
0.0243 - 0.0358i	-0.0014 + 0.0065i	-0.0355 - 0.0145i
0.0357 - 0.0520i	-0.0003 + 0.0014i	0.0291 + 0.0124i
-0.0083 + 0.0108i	0.0007 - 0.0037i	-0.0037 - 0.0022i
0.0004 - 0.0008i	-0.0020 + 0.0104i	0.0005 + 0.0002i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 2

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.8191	0.3973	78.4308	0.4223	0.1903	0.0370
2	11.9256	0.3581	96.2767	0.6027	0.2956	**Modal Density**
3	10.9773	0.3188	91.1793	0.5168	0.2848	1.4543
4	14.2569	0.3897	96.6114	0.6190	0.4798	**File Name**
5	13.3297	0.5615	96.5365	0.5925	0.2770	analy_orange_2
6	15.3829	0.4149	78.3520	0.5337	0.3324	



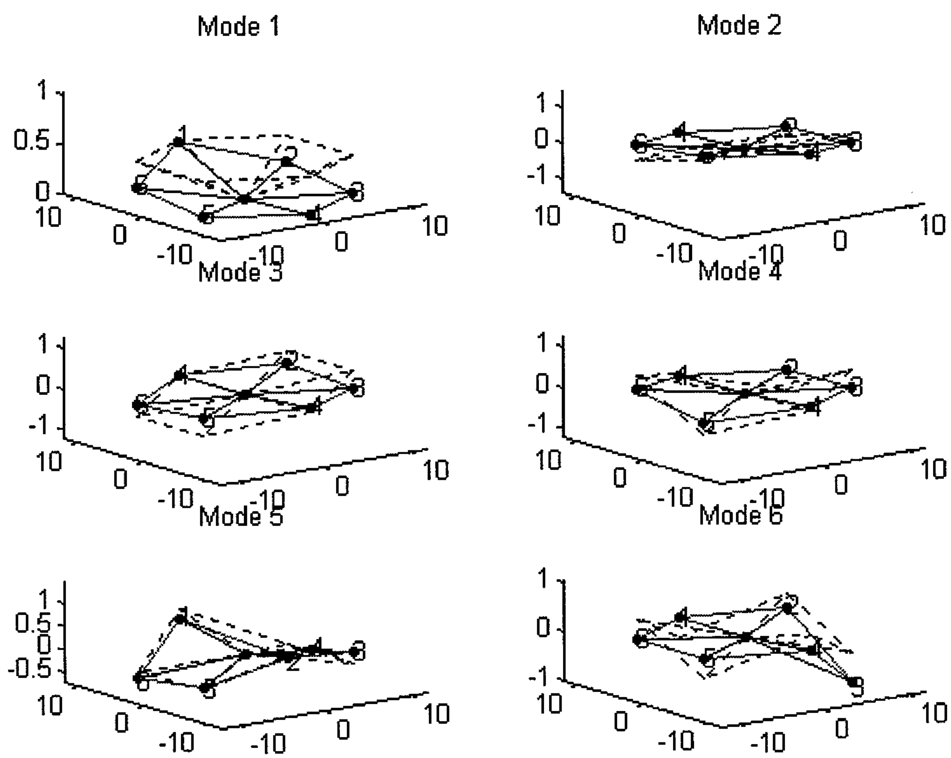
Mode 1	Mode2	Mode 3
0.0025 + 0.0031i	-0.0122 - 0.0052i	-0.0055 - 0.0013i
0.0093 + 0.0092i	-0.0479 - 0.0178i	-0.0056 - 0.0028i
0.0057 + 0.0071i	-0.0099 - 0.0039i	0.0077 + 0.0025i
0.0194 + 0.0299i	0.0088 + 0.0004i	0.0353 + 0.0131i
0.0181 + 0.0282i	0.0140 + 0.0026i	-0.0388 - 0.0143i
0.0025 + 0.0050i	-0.0001 - 0.0009i	-0.0094 - 0.0032i
Mode 4	**Mode 5**	**Mode 6**
0.0068 + 0.0086i	0.0101 - 0.0681i	-0.0251 - 0.0225i
-0.0092 - 0.0137i	-0.0017 + 0.0133i	0.0036 + 0.0032i
0.0338 + 0.0536i	-0.0022 + 0.0153i	-0.0020 - 0.0017i
-0.0067 - 0.0105i	0.0003 - 0.0063i	0.0013 + 0.0011i
0.0007 + 0.0013i	-0.0012 + 0.0082i	-0.0082 - 0.0073i
0.0042 + 0.0064i	0.0051 - 0.0277i	0.0671 + 0.0624i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9665	0.4337	94.1276	0.5950	0.4155	0.0616
2	10.2515	0.3504	96.0325	0.6371	0.3659	**Modal Density**
3	10.7567	0.3924	96.9139	0.7015	0.5709	0.8141
4	12.4112	0.3736	95.9386	0.5366	0.3292	**File Name**
5	11.9609	0.3915	98.4517	0.6529	0.3960	analy_orange_3
6	13.4238	0.4840	98.0083	0.4385	0.2177	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 3

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25



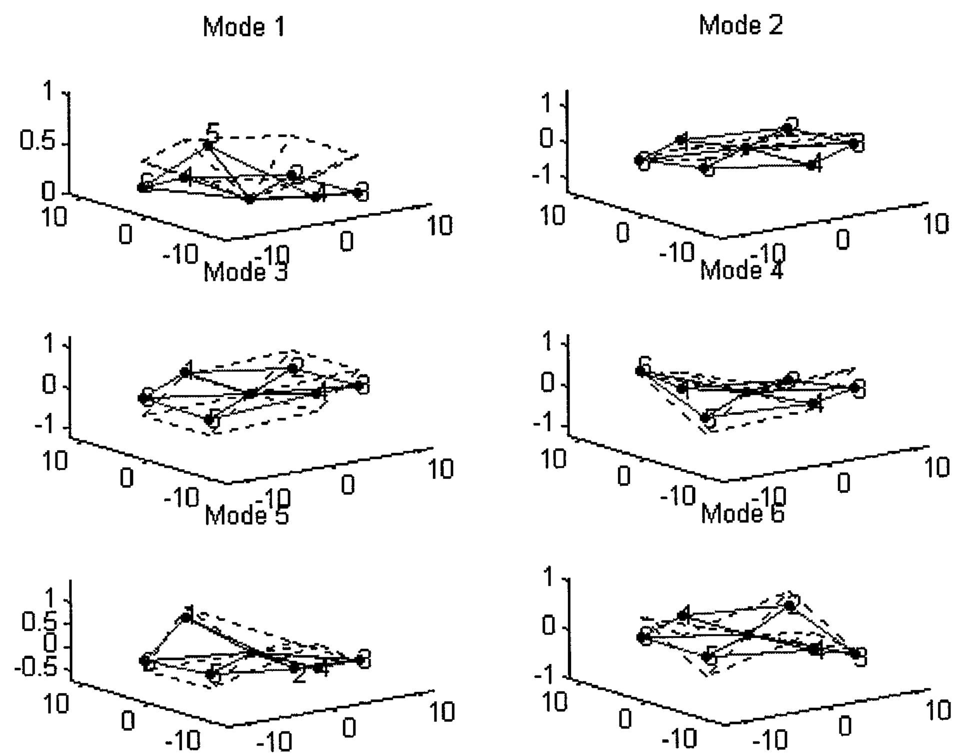
Mode 1	Mode2	Mode 3
0.0273 + 0.0545i	-0.0088 + 0.0136i	-0.0021 - 0.0107i
0.0118 + 0.0232i	-0.0055 + 0.0076i	0.0220 + 0.0715i
0.0018 + 0.0038i	0.0028 - 0.0036i	0.0058 + 0.0178i
0.0023 + 0.0062i	0.0285 - 0.0387i	0.0144 + 0.0433i
0.0043 + 0.0099i	0.0312 - 0.0445i	-0.0048 - 0.0112i
0.0109 + 0.0216i	0.0127 - 0.0182i	-0.0179 - 0.0520i
Mode 4	**Mode 5**	**Mode 6**
-0.0038 + 0.0140i	0.0346 - 0.0112i	-0.0007 + 0.0003i
0.0007 - 0.0051i	-0.0553 + 0.0177i	0.0051 - 0.0006i
0.0018 - 0.0071i	-0.0022 + 0.0009i	-0.0388 + 0.0037i
0.0094 - 0.0336i	0.0476 - 0.0139i	0.0039 - 0.0004i
-0.0159 + 0.0582i	-0.0242 + 0.0077i	-0.0001 + 0.0002i
0.0146 - 0.0521i	-0.0438 + 0.0122i	0.0008 + 0.0001i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.7000	0.4091	98.7505	0.4807	0.3027	0.0265
2	12.4123	0.3920	98.0385	0.8314	0.6529	**Modal Density**
3	12.9454	0.3922	99.2778	0.7112	0.7126	1.1713
4	13.8290	0.2849	98.6490	0.7449	0.6982	**File Name**
5	13.3204	0.3550	97.8995	0.9886	1.0216	analy_orange_4
6	17.2403	0.4123	61.3830	0.4141	0.1763	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 4

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40



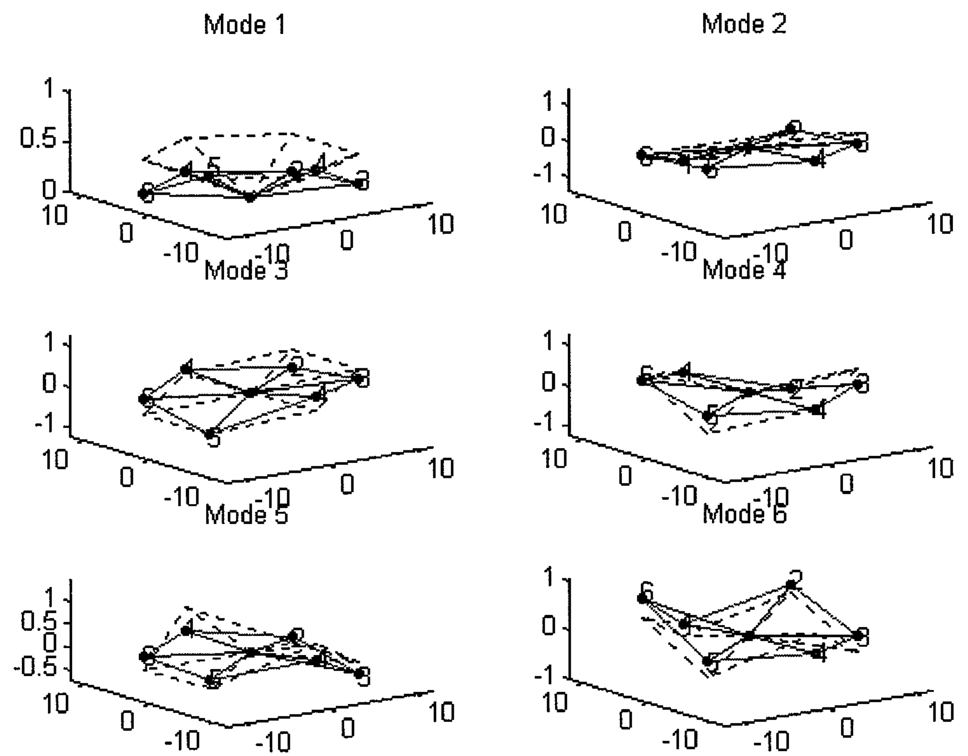
Mode 1	Mode2	Mode 3
0.0017 + 0.0017i	-0.0301 + 0.0579i	0.0047 - 0.0140i
0.0005 + 0.0005i	-0.0103 + 0.0187i	0.0052 - 0.0114i
0.0016 + 0.0010i	-0.0012 + 0.0018i	0.0068 - 0.0129i
0.0135 + 0.0089i	0.0035 - 0.0087i	0.0395 - 0.0720i
0.0458 + 0.0322i	0.0055 - 0.0102i	-0.0082 + 0.0166i
0.0098 + 0.0065i	-0.0244 + 0.0467i	-0.0042 + 0.0042i
Mode 4	**Mode 5**	**Mode 6**
-0.0374 - 0.0283i	0.0243 + 0.0102i	-0.0002 - 0.0014i
-0.0268 - 0.0213i	-0.0594 - 0.0246i	0.0044 + 0.0092i
-0.0027 - 0.0027i	-0.0154 - 0.0065i	-0.0179 - 0.0307i
0.0152 + 0.0083i	0.0052 + 0.0012i	0.0023 + 0.0023i
-0.0119 - 0.0084i	0.0003 + 0.0001i	-0.0001 - 0.0004i
0.0577 + 0.0445i	-0.0084 - 0.0036i	0.0006 + 0.0003i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 5

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9717	0.3149	92.4981	0.4341	0.2111	0.0261
2	12.6135	0.4481	95.3068	0.7776	0.5713	**Modal Density**
3	13.0147	0.5427	98.2624	0.5346	0.3250	1.5111
4	13.6224	0.3549	98.0324	0.6583	0.6135	**File Name**
5	14.6374	0.4003	92.2184	0.6485	0.3852	analy_orange_5
6	17.3863	0.3803	68.3345	0.4266	0.1975	



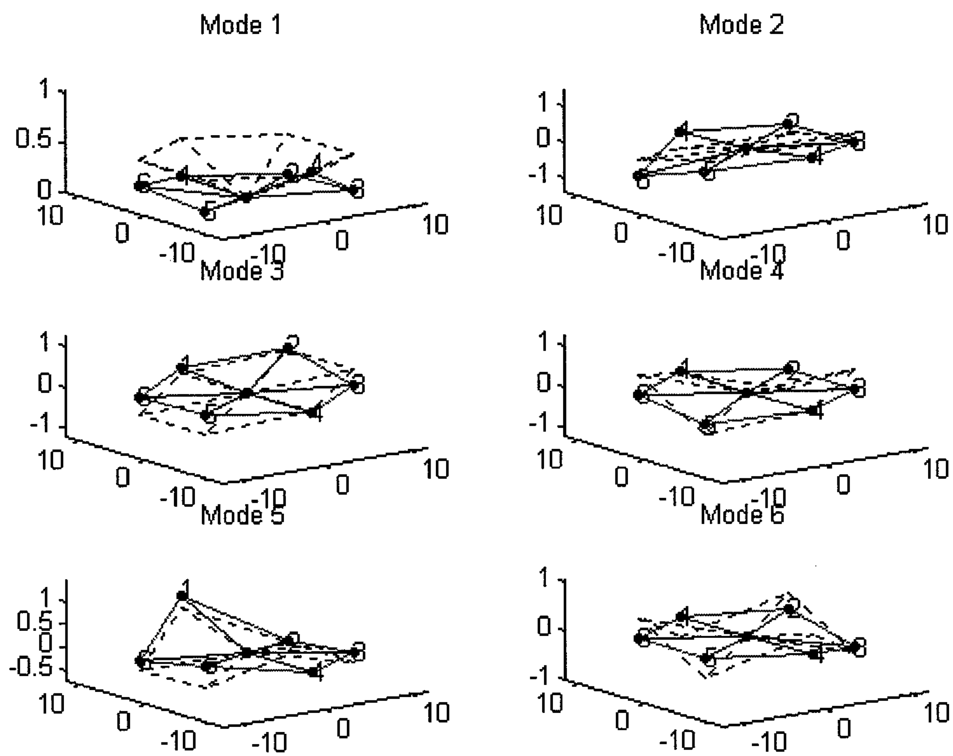
Mode 1	Mode2	Mode 3
0.0036 - 0.0046i	-0.0603 - 0.0017i	0.0039 + 0.0025i
0.0019 - 0.0026i	-0.0110 - 0.0004i	0.0042 + 0.0043i
0.0074 - 0.0094i	-0.0005 + 0.0001i	0.0146 + 0.0156i
0.0292 - 0.0329i	0.0095 + 0.0003i	0.0226 + 0.0276i
0.0281 - 0.0294i	0.0010 + 0.0006i	-0.0324 - 0.0367i
0.0045 - 0.0047i	-0.0108 - 0.0001i	-0.0048 - 0.0054i
Mode 4	**Mode 5**	**Mode 6**
0.0006 - 0.0016i	0.0046 - 0.0058i	-0.0099 + 0.0017i
-0.0325 + 0.0467i	-0.0108 + 0.0133i	0.0341 - 0.0053i
0.0055 - 0.0084i	-0.0374 + 0.0474i	-0.0058 + 0.0008i
-0.0002 + 0.0004i	0.0163 - 0.0211i	0.0013 - 0.0004i
-0.0029 + 0.0036i	-0.0064 + 0.0092i	-0.0056 + 0.0009i
0.0258 - 0.0304i	-0.0004 + 0.0006i	0.0494 - 0.0086i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.6195	0.4266	94.3137	0.5732	0.3737	0.1292
2	11.1109	0.3940	92.0782	0.6029	0.2965	**Modal Density**
3	11.4665	0.4257	97.1873	0.6645	0.5918	0.9683
4	14.7372	0.2062	84.0543	0.6185	0.4712	**File Name**
5	12.2878	0.3415	86.4513	0.6645	0.4195	analy_orange_6
6	14.8989	0.3951	90.0629	0.5067	0.3225	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 6

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



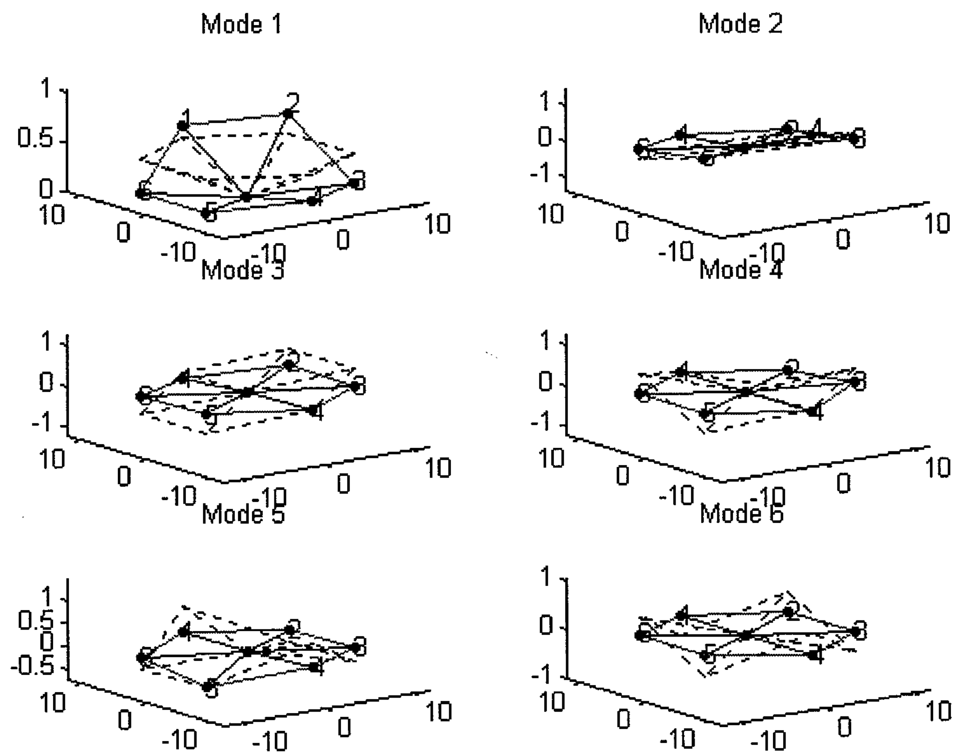
Mode 1	Mode2	Mode 3
0.0013 - 0.0016i	-0.0053 + 0.0041i	0.0142 - 0.0209i
0.0007 - 0.0010i	-0.0007 + 0.0007i	0.0486 - 0.0735i
0.0023 - 0.0041i	0.0011 - 0.0008i	0.0077 - 0.0117i
0.0238 - 0.0422i	0.0119 - 0.0089i	-0.0011 + 0.0018i
0.0044 - 0.0076i	-0.0030 + 0.0025i	-0.0011 + 0.0016i
0.0082 - 0.0099i	-0.0354 + 0.0277i	-0.0022 + 0.0037i
Mode 4	Mode 5	Mode 6
0.0038 - 0.0113i	0.0506 - 0.0293i	-0.0002 + 0.0014i
-0.0014 + 0.0038i	-0.0139 + 0.0073i	0.0028 - 0.0049i
0.0000 - 0.0004i	-0.0044 + 0.0025i	-0.0111 + 0.0372i
0.0019 - 0.0056i	-0.0006 + 0.0004i	0.0011 - 0.0027i
-0.0181 + 0.0664i	0.0121 - 0.0040i	-0.0001 + 0.0004i
0.0010 - 0.0042i	-0.0050 + 0.0029i	0.0002 - 0.0002i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.3163	0.1817	90.2962	0.4311	0.2059	0.0689
2	10.4919	0.3690	91.0317	0.6166	0.3212	**Modal Density**
3	12.7574	0.4218	95.7412	0.5270	0.3063	1.8065
4	14.7014	0.3033	94.4926	0.5111	0.2726	**File Name**
5	14.9498	0.4673	91.4444	0.6157	0.3209	analy_orange_7
6	17.2827	0.3539	68.3779	0.4139	0.1760	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 7

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



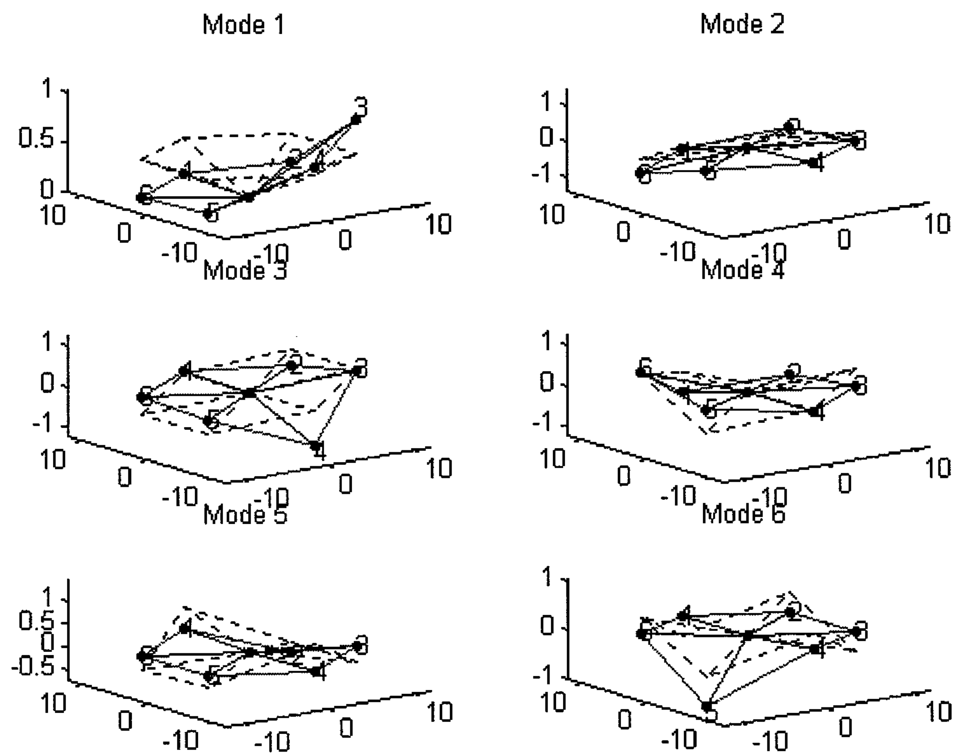
Mode 1	Mode2	Mode 3
0.0355 - 0.0233i	-0.0129 + 0.0071i	-0.0109 + 0.0519i
0.0423 - 0.0276i	-0.0109 + 0.0090i	0.0088 - 0.0470i
0.0082 - 0.0058i	0.0059 + 0.0022i	0.0019 - 0.0097i
0.0114 - 0.0088i	0.0505 + 0.0051i	-0.0007 + 0.0032i
0.0047 - 0.0027i	0.0167 - 0.0001i	-0.0019 + 0.0062i
0.0052 - 0.0035i	0.0003 + 0.0007i	-0.0019 + 0.0093i
Mode 4	Mode 5	Mode 6
-0.0001 + 0.0009i	0.0022 - 0.0066i	-0.0004 - 0.0041i
-0.0013 - 0.0094i	-0.0015 + 0.0054i	0.0000 + 0.0005i
0.0079 + 0.0559i	0.0019 - 0.0067i	-0.0001 - 0.0004i
-0.0014 - 0.0089i	0.0080 - 0.0263i	-0.0005 + 0.0006i
0.0008 + 0.0016i	-0.0274 + 0.0881i	0.0009 - 0.0067i
0.0002 + 0.0012i	-0.0044 + 0.0148i	0.0024 + 0.0417i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 8

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 50

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.4688	0.5992	95.9238	0.5559	0.3802	0.0190
2	11.6999	0.5737	92.2069	0.6547	0.4033	**Modal Density**
3	12.3634	0.2724	97.4213	0.6888	0.5415	1.1894
4	15.0357	0.3636	85.7971	0.5137	0.2782	**File Name**
5	13.2854	0.4603	95.9360	0.6141	0.3172	analy_orange_8
6	16.9697	0.3025	69.7523	0.4157	0.1791	



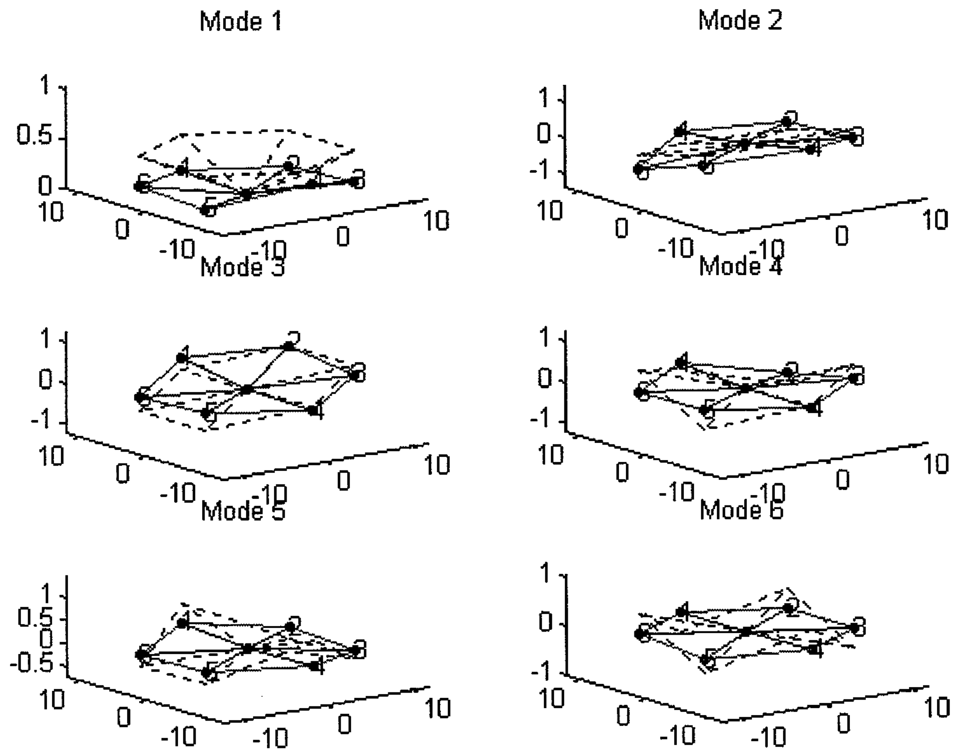
Mode 1	Mode2	Mode 3
0.0029 + 0.0008i	-0.0410 - 0.0162i	0.0011 + 0.0007i
0.0077 + 0.0034i	-0.0081 - 0.0030i	0.0061 + 0.0018i
0.0412 + 0.0180i	0.0017 + 0.0011i	0.0265 + 0.0061i
0.0271 + 0.0127i	0.0044 + 0.0004i	-0.0544 - 0.0142i
0.0035 + 0.0016i	-0.0047 - 0.0023i	-0.0082 - 0.0021i
0.0024 + 0.0005i	-0.0409 - 0.0161i	-0.0028 - 0.0005i
Mode 4	Mode 5	Mode 6
-0.0372 + 0.0321i	0.0060 - 0.0108i	-0.0001 - 0.0005i
-0.0101 + 0.0089i	-0.0342 + 0.0579i	0.0000 - 0.0005i
0.0026 - 0.0025i	0.0029 - 0.0051i	-0.0002 - 0.0002i
-0.0028 + 0.0026i	-0.0001 + 0.0002i	0.0032 - 0.0003i
0.0057 - 0.0050i	-0.0005 + 0.0008i	-0.0434 - 0.0056i
0.0397 - 0.0345i	-0.0007 + 0.0019i	0.0041 + 0.0007i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 9

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.3928	0.3361	94.0240	0.4990	0.3105	0.0077
2	11.5094	0.5756	95.3520	0.8283	0.5324	**Modal Density**
3	11.2721	0.4292	92.2966	0.5640	0.3834	1.6474
4	12.4586	0.2844	98.2022	0.7015	0.5488	**File Name**
5	14.7425	0.2961	81.8327	0.5894	0.2712	analy_orange_9
6	16.9098	0.2341	64.8284	0.4112	0.1715	



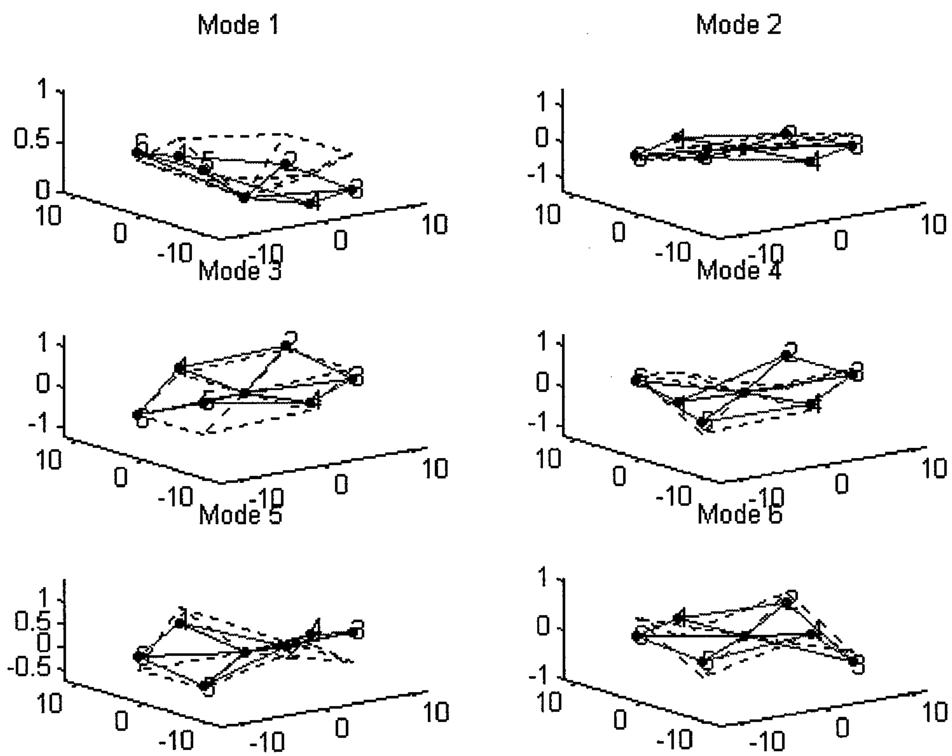
Mode 1	Mode2	Mode 3
0.0029 + 0.0082i	-0.0089 - 0.0083i	0.0175 - 0.0198i
0.0028 + 0.0063i	-0.0014 - 0.0019i	0.0341 - 0.0396i
0.0048 + 0.0096i	0.0028 + 0.0023i	0.0162 - 0.0193i
0.0157 + 0.0395i	0.0150 + 0.0106i	-0.0056 + 0.0082i
0.0042 + 0.0112i	-0.0010 - 0.0011i	-0.0033 + 0.0038i
0.0065 + 0.0234i	-0.0265 - 0.0220i	-0.0091 + 0.0113i
Mode 4	Mode 5	Mode 6
0.0094 + 0.0358i	0.0094 - 0.0489i	-0.0005 + 0.0024i
-0.0137 - 0.0502i	-0.0008 + 0.0062i	0.0001 - 0.0009i
0.0117 + 0.0450i	-0.0066 + 0.0404i	-0.0004 + 0.0023i
-0.0022 - 0.0068i	0.0018 - 0.0092i	0.0010 - 0.0107i
-0.0004 - 0.0055i	-0.0002 + 0.0007i	-0.0118 + 0.0973i
-0.0019 - 0.0064i	-0.0026 + 0.0139i	0.0010 - 0.0097i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 10

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.6610	0.4015	95.3074	0.5064	0.3525	0.0487
2	9.8000	0.2970	89.7882	0.6899	0.4646	**Modal Density**
3	10.5966	0.4356	98.0876	0.6346	0.5758	0.8712
4	11.8603	0.3017	97.6352	0.7664	0.7294	**File Name**
5	11.3565	0.2878	94.1561	0.7758	0.5575	analy_orange_10
6	13.2156	0.5456	91.1740	0.4130	0.1745	



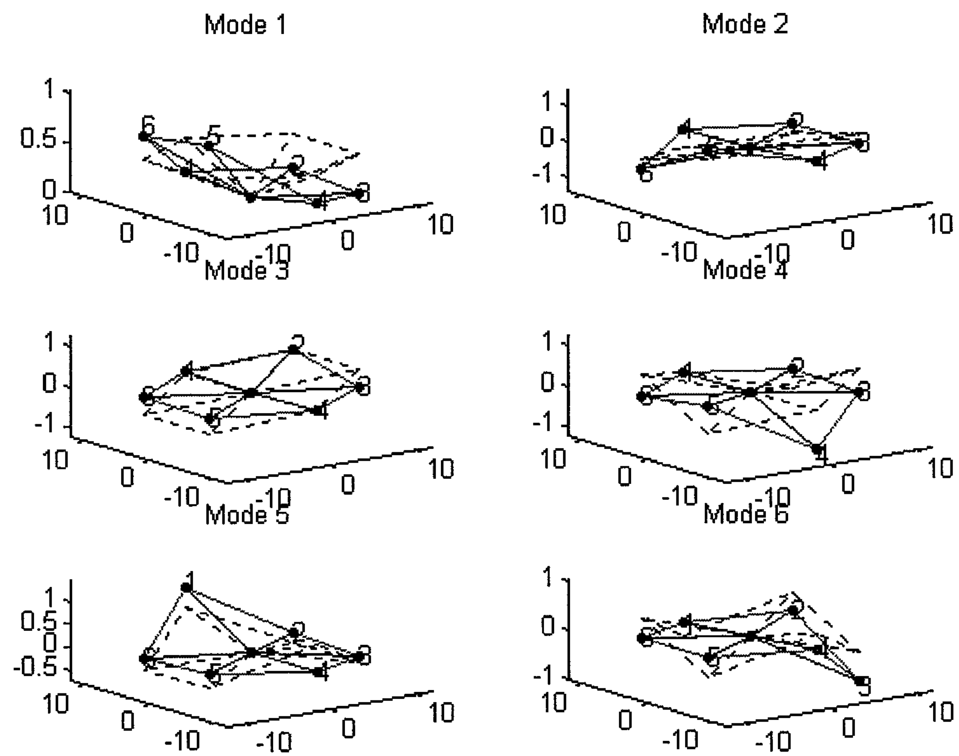
Mode 1	Mode2	Mode 3
0.0132 - 0.0109i	-0.0211 + 0.0301i	0.0067 + 0.0037i
0.0069 - 0.0053i	-0.0193 + 0.0270i	0.0369 + 0.0179i
0.0027 - 0.0021i	-0.0033 + 0.0045i	0.0159 + 0.0070i
0.0085 - 0.0068i	0.0075 - 0.0104i	0.0143 + 0.0062i
0.0302 - 0.0252i	0.0237 - 0.0335i	0.0169 + 0.0080i
0.0295 - 0.0251i	-0.0126 + 0.0181i	-0.0313 - 0.0152i
Mode 4	**Mode 5**	**Mode 6**
-0.0521 - 0.0104i	0.0167 - 0.0020i	-0.0051 + 0.0045i
0.0249 + 0.0043i	-0.0278 + 0.0023i	0.0167 - 0.0148i
0.0227 + 0.0046i	0.0266 - 0.0018i	-0.0487 + 0.0426i
0.0113 + 0.0023i	0.0595 - 0.0041i	0.0352 - 0.0300i
-0.0125 - 0.0026i	-0.0176 + 0.0013i	-0.0069 + 0.0060i
0.0249 + 0.0047i	-0.0003 + 0.0005i	0.0022 - 0.0018i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 11

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.0112	0.3169	98.5436	0.6185	0.4416	0.0901
2	10.5489	0.2834	97.9328	0.9756	0.9449	**Modal Density**
3	10.8226	0.3562	98.7659	0.7558	0.8091	0.5984
4	11.5558	0.2999	98.7526	0.6609	0.6671	**File Name**
5	11.8532	0.3228	98.0917	0.7269	0.5703	analy_orange_11
6	12.6571	0.3390	98.7918	0.5263	0.3611	



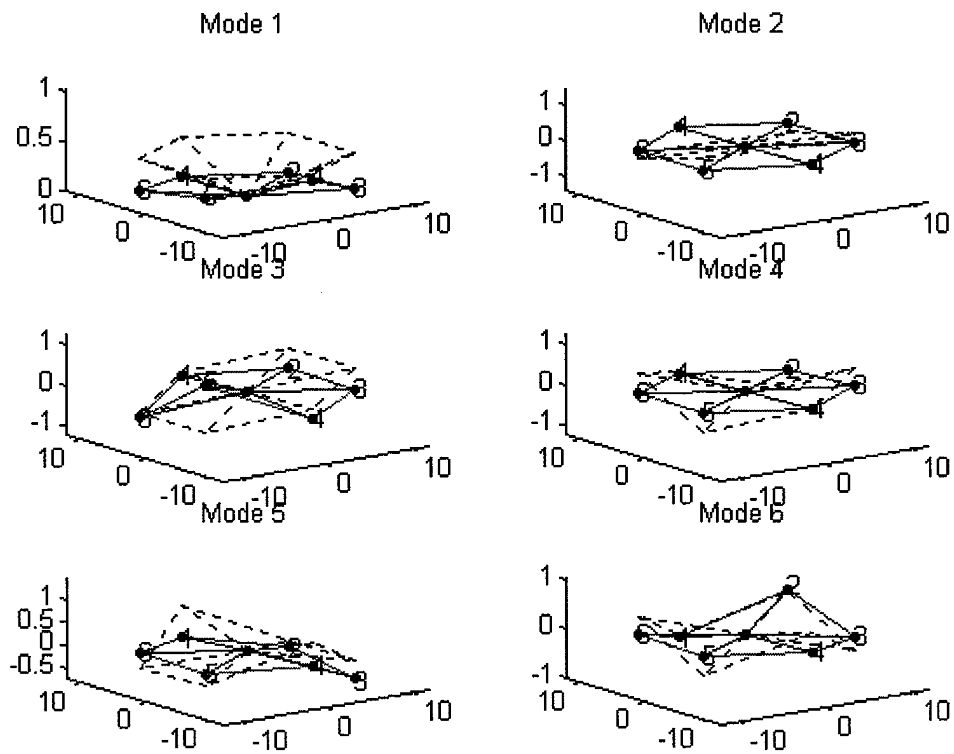
Mode 1	Mode2	Mode 3
0.0037 - 0.0002i	-0.0033 - 0.0027i	0.0025 + 0.0042i
0.0044 - 0.0003i	0.0016 + 0.0019i	0.0257 + 0.0439i
0.0009 + 0.0002i	0.0004 + 0.0007i	0.0023 + 0.0038i
0.0075 + 0.0007i	0.0070 + 0.0063i	-0.0002 - 0.0006i
0.0394 - 0.0000i	0.0299 + 0.0235i	-0.0052 - 0.0057i
0.0342 - 0.0014i	-0.0332 - 0.0278i	-0.0018 - 0.0015i
Mode 4	Mode 5	Mode 6
0.0001 - 0.0000i	0.0430 + 0.0054i	-0.0059 - 0.0004i
0.0011 - 0.0004i	-0.0019 - 0.0002i	0.0021 - 0.0000i
-0.0075 + 0.0019i	-0.0057 - 0.0020i	-0.0392 + 0.0007i
-0.0656 + 0.0177i	0.0003 - 0.0002i	0.0036 - 0.0001i
0.0117 - 0.0033i	0.0000 - 0.0004i	-0.0002 - 0.0001i
-0.0020 + 0.0004i	-0.0026 - 0.0003i	0.0004 + 0.0001i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.5175	0.4063	93.9438	0.5501	0.3491	0.0331
2	10.1467	0.1931	94.7752	0.7814	0.5251	**Modal Density**
3	9.7549	0.3713	86.9895	0.5105	0.2714	2.2630
4	11.9169	0.4408	78.2870	0.5115	0.2735	**File Name**
5	16.9342	0.3138	75.1543	0.5846	0.2626	analy_orange_12
6	17.1922	0.3376	81.0628	0.4151	0.1781	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 12

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40



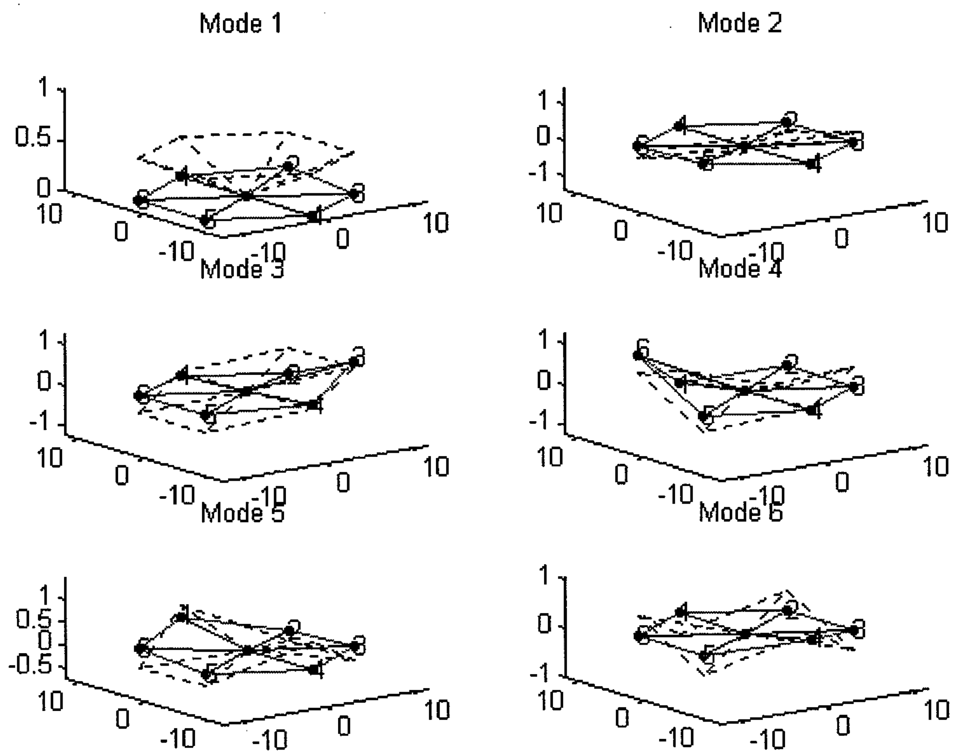
Mode 1	Mode2	Mode 3
0.0005 - 0.0011i	-0.0007 + 0.0066i	-0.0058 - 0.0029i
0.0003 - 0.0009i	-0.0003 + 0.0001i	-0.0012 - 0.0009i
0.0024 - 0.0048i	0.0003 - 0.0036i	-0.0023 - 0.0016i
0.0173 - 0.0368i	0.0010 - 0.0230i	-0.0128 - 0.0063i
0.0101 - 0.0214i	-0.0021 + 0.0295i	0.0390 + 0.0196i
0.0043 - 0.0089i	-0.0023 + 0.0436i	-0.0334 - 0.0173i
Mode 4	**Mode 5**	**Mode 6**
-0.0050 + 0.0564i	-0.0130 - 0.0113i	-0.0228 - 0.0283i
-0.0039 + 0.0495i	-0.0388 - 0.0331i	0.0233 + 0.0286i
0.0041 - 0.0297i	-0.0670 - 0.0559i	-0.0057 - 0.0076i
-0.0001 + 0.0022i	0.0072 + 0.0061i	0.0008 + 0.0006i
0.0000 + 0.0005i	-0.0015 - 0.0012i	0.0000 - 0.0000i
0.0006 - 0.0062i	0.0023 + 0.0021i	0.0022 + 0.0026i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 13

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.5692	0.2593	84.9153	0.4857	0.2986	0.0189
2	10.2697	0.4806	90.8739	0.7672	0.6053	**Modal Density**
3	10.9028	0.2012	95.4950	0.6846	0.5631	1.5882
4	14.2869	0.4048	91.4544	0.7183	0.6373	**File Name**
5	13.1003	0.4266	97.5722	0.6815	0.4341	analy_orange_13
6	15.3950	0.4563	79.4140	0.5838	0.3585	



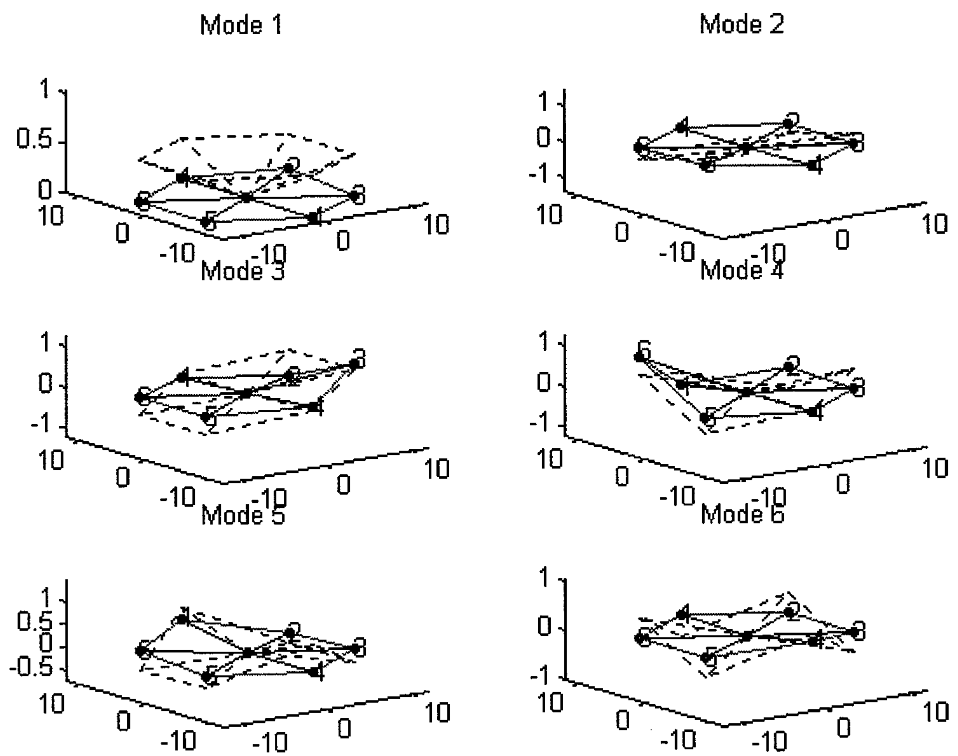
Mode 1	Mode2	Mode 3
0.0004 + 0.0009i	-0.0116 + 0.0077i	0.0037 - 0.0154i
0.0014 + 0.0019i	-0.0056 + 0.0033i	0.0123 - 0.0538i
0.0048 + 0.0066i	0.0006 - 0.0009i	0.0060 - 0.0305i
0.0277 + 0.0358i	0.0079 - 0.0065i	-0.0015 + 0.0071i
0.0076 + 0.0108i	-0.0127 + 0.0117i	-0.0019 + 0.0107i
0.0022 + 0.0041i	-0.0432 + 0.0357i	-0.0021 + 0.0067i
Mode 4	**Mode 5**	**Mode 6**
-0.0241 + 0.0061i	0.0024 + 0.0043i	-0.0528 - 0.0707i
-0.0339 + 0.0124i	-0.0039 - 0.0111i	0.0195 + 0.0248i
0.0590 - 0.0188i	0.0001 + 0.0027i	-0.0073 - 0.0094i
-0.0128 + 0.0039i	0.0042 + 0.0114i	0.0015 + 0.0016i
0.0122 - 0.0041i	-0.0216 - 0.0619i	-0.0043 - 0.0051i
0.0043 - 0.0008i	0.0071 + 0.0201i	0.0108 + 0.0138i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 14

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2287	0.2476	93.0972	0.4344	0.2118	0.0231
2	11.0251	0.4338	95.7961	0.6335	0.3574	**Modal Density**
3	11.5147	0.3815	96.7462	0.6065	0.4879	0.7256
4	12.5186	0.3144	98.2773	0.6314	0.5554	**File Name**
5	12.3180	0.3177	96.8108	0.6270	0.3432	analy_orange_14
6	13.4367	0.5327	97.4134	0.4457	0.2326	



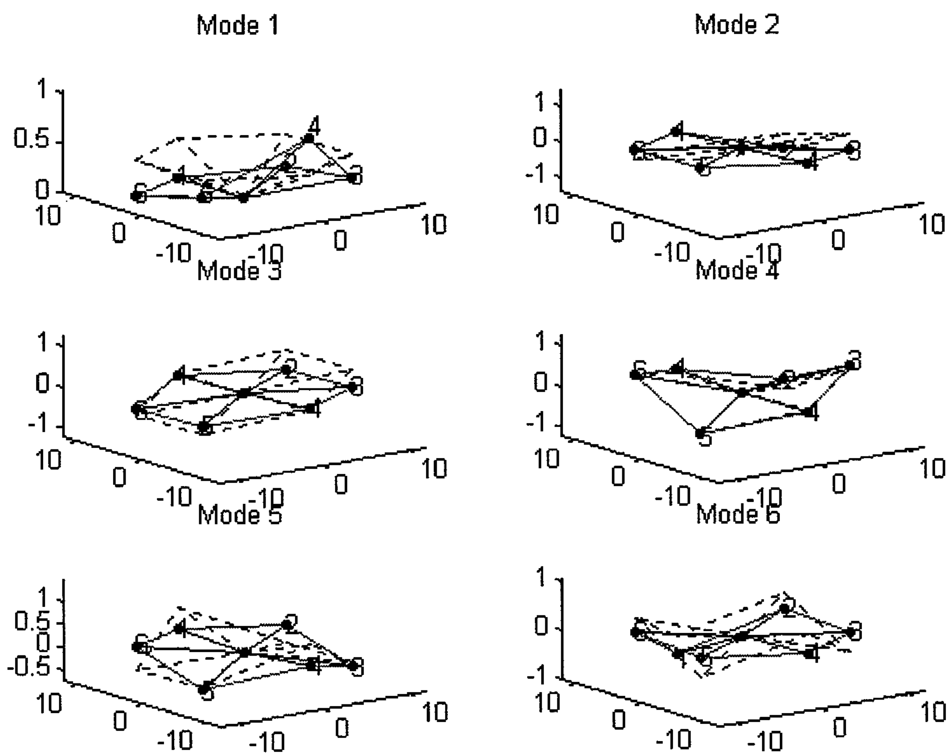
Mode 1	Mode2	Mode 3
0.0003 - 0.0104i	0.0000 - 0.0018i	-0.0059 - 0.0101i
0.0036 - 0.0514i	0.0003 + 0.0030i	-0.0089 - 0.0085i
0.0000 - 0.0123i	0.0001 - 0.0011i	0.0385 + 0.0429i
-0.0002 - 0.0015i	0.0007 - 0.0062i	0.0054 + 0.0063i
-0.0002 - 0.0008i	0.0072 - 0.0514i	-0.0019 - 0.0009i
-0.0001 - 0.0015i	0.0019 - 0.0095i	-0.0017 - 0.0037i
Mode 4	**Mode 5**	**Mode 6**
-0.0322 - 0.0040i	0.0214 + 0.0639i	0.0003 + 0.0004i
0.0033 + 0.0004i	-0.0046 - 0.0123i	0.0005 + 0.0001i
-0.0005 - 0.0000i	0.0023 + 0.0084i	-0.0006 + 0.0024i
-0.0024 - 0.0003i	0.0002 + 0.0004i	0.0093 - 0.0359i
-0.0103 - 0.0012i	-0.0024 - 0.0064i	-0.0003 + 0.0023i
0.0905 + 0.0131i	0.0076 + 0.0265i	0.0005 - 0.0002i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.6683	0.5489	82.4102	0.4281	0.2006	0.0015
2	10.3386	0.2663	85.2495	0.5929	0.2776	**Modal Density**
3	11.4260	0.3669	94.2115	0.5277	0.3088	2.0195
4	13.3903	0.5177	95.5369	0.5340	0.3202	**File Name**
5	11.9460	0.3178	91.2952	0.6407	0.3682	analy_orange_15
6	16.8003	0.1660	67.5190	0.4100	0.1696	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 15

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



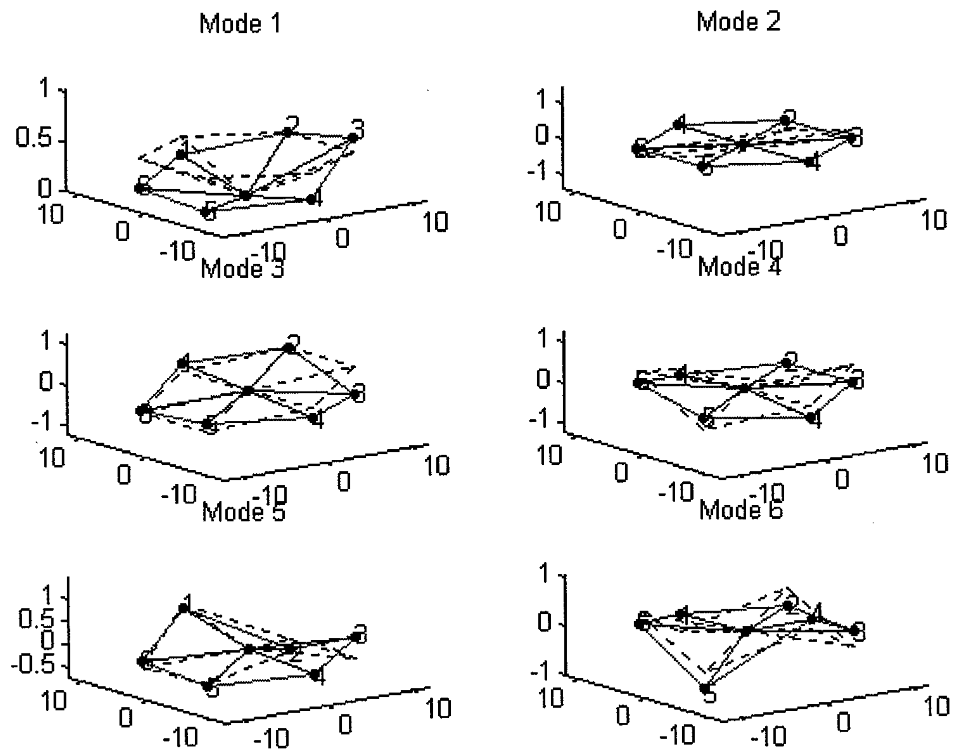
Mode 1	Mode2	Mode 3
0.0009 + 0.0004i	-0.0064 + 0.0062i	-0.0040 - 0.0085i
0.0048 + 0.0030i	-0.0397 + 0.0385i	-0.0002 + 0.0004i
0.0082 + 0.0055i	-0.0117 + 0.0106i	0.0035 + 0.0067i
0.0393 + 0.0233i	0.0058 - 0.0063i	0.0052 + 0.0109i
0.0117 + 0.0066i	0.0030 - 0.0025i	-0.0191 - 0.0400i
0.0031 + 0.0007i	-0.0011 + 0.0013i	-0.0225 - 0.0470i
Mode 4	Mode 5	Mode 6
0.0049 - 0.0009i	0.0056 + 0.0085i	-0.0480 - 0.0397i
-0.0183 + 0.0057i	0.0068 + 0.0112i	0.0055 + 0.0041i
0.0448 - 0.0144i	-0.0246 - 0.0390i	-0.0008 - 0.0006i
-0.0015 + 0.0007i	0.0084 + 0.0129i	0.0001 - 0.0003i
-0.0371 + 0.0096i	-0.0224 - 0.0318i	-0.0012 - 0.0007i
0.0384 - 0.0094i	0.0147 + 0.0219i	0.0077 + 0.0064i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 16

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2099	0.3941	92.0476	0.4386	0.2199	0.0349
2	10.9149	0.2567	94.4233	0.6160	0.3214	**Modal Density**
3	11.6047	0.4004	91.1709	0.6766	0.5482	1.1188
4	12.3823	0.2954	96.9886	0.7973	0.8247	**File Name**
5	12.4584	0.4416	98.6869	0.8720	0.7949	analy_orange_16
6	14.8616	0.3229	90.7108	0.4161	0.1797	



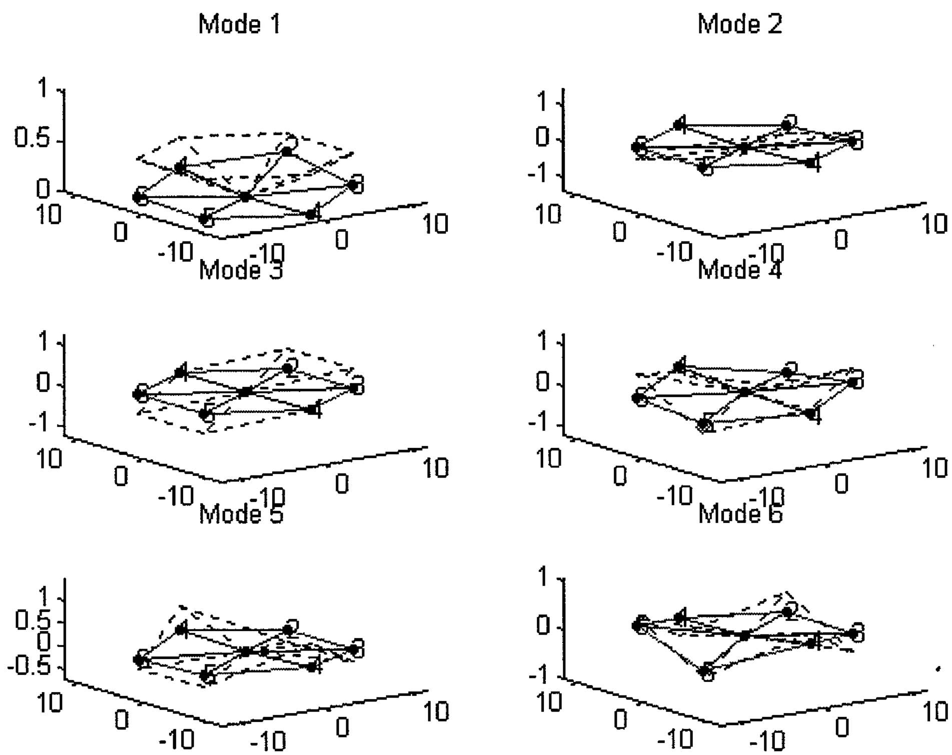
Mode 1	Mode2	Mode 3
0.0154 - 0.0132i	-0.0024 - 0.0429i	0.0153 - 0.0133i
0.0283 - 0.0247i	-0.0008 - 0.0127i	0.0422 - 0.0322i
0.0368 - 0.0331i	0.0017 + 0.0278i	-0.0158 + 0.0126i
0.0103 - 0.0097i	0.0000 + 0.0055i	-0.0195 + 0.0157i
0.0042 - 0.0041i	-0.0009 - 0.0112i	-0.0257 + 0.0206i
0.0081 - 0.0073i	-0.0034 - 0.0427i	-0.0389 + 0.0305i
Mode 4	Mode 5	Mode 6
-0.0143 - 0.0283i	0.0447 + 0.0310i	-0.0059 + 0.0012i
0.0045 + 0.0097i	-0.0441 - 0.0317i	0.0042 - 0.0011i
0.0053 + 0.0104i	0.0171 + 0.0128i	-0.0091 + 0.0018i
-0.0262 - 0.0527i	-0.0126 - 0.0111i	0.0565 - 0.0106i
-0.0173 - 0.0354i	-0.0279 - 0.0217i	-0.0648 + 0.0126i
0.0185 + 0.0372i	-0.0150 - 0.0094i	0.0176 - 0.0033i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9964	0.3242	97.9542	0.5608	0.4339	0.0826
2	11.4869	0.3241	98.9164	0.9284	0.7682	**Modal Density**
3	11.9597	0.2826	99.1639	0.8311	0.9593	0.5509
4	12.7843	0.3363	99.1740	0.7599	0.8681	**File Name**
5	12.6253	0.3222	99.3929	0.9620	0.8692	analy_orange_17
6	13.6944	0.3616	98.2939	0.5575	0.3664	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 17

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



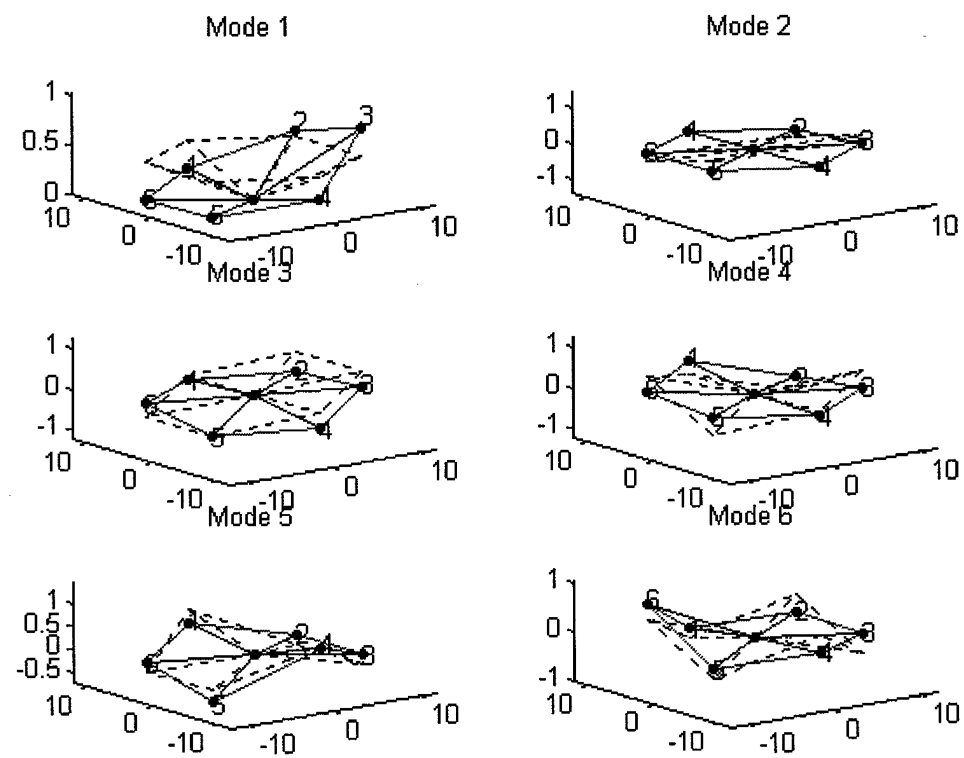
Mode 1	Mode2	Mode 3
0.0063 + 0.0207i	0.0018 + 0.0178i	-0.0019 - 0.0647i
0.0147 + 0.0525i	-0.0032 - 0.0277i	0.0007 + 0.0106i
0.0051 + 0.0184i	0.0030 + 0.0387i	0.0015 + 0.0396i
0.0017 + 0.0049i	0.0041 + 0.0435i	-0.0005 + 0.0180i
0.0010 + 0.0021i	0.0032 + 0.0359i	-0.0006 - 0.0036i
0.0020 + 0.0051i	0.0029 + 0.0246i	-0.0008 - 0.0297i
Mode 4	Mode 5	Mode 6
0.0107 - 0.0315i	0.0034 - 0.0251i	-0.0048 + 0.0116i
-0.0073 + 0.0223i	0.0002 - 0.0004i	0.0016 - 0.0036i
0.0146 - 0.0429i	-0.0029 + 0.0241i	-0.0045 + 0.0094i
-0.0098 + 0.0265i	0.0089 - 0.0643i	0.0172 - 0.0357i
-0.0214 + 0.0596i	-0.0015 + 0.0116i	-0.0240 + 0.0518i
-0.0077 + 0.0229i	-0.0088 + 0.0677i	0.0190 - 0.0424i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 18

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.7886	0.4457	92.3821	0.4656	0.2711	0.1062
2	12.1064	0.3431	99.4419	1.0584	1.1881	**Modal Density**
3	11.9349	0.3025	98.6843	0.6505	0.6011	0.6619
4	12.7116	0.3651	99.4964	0.7527	0.9069	**File Name**
5	13.3035	0.4128	92.8091	0.8556	0.6512	analy_orange_18
6	13.9081	0.2907	98.3681	0.6096	0.4951	



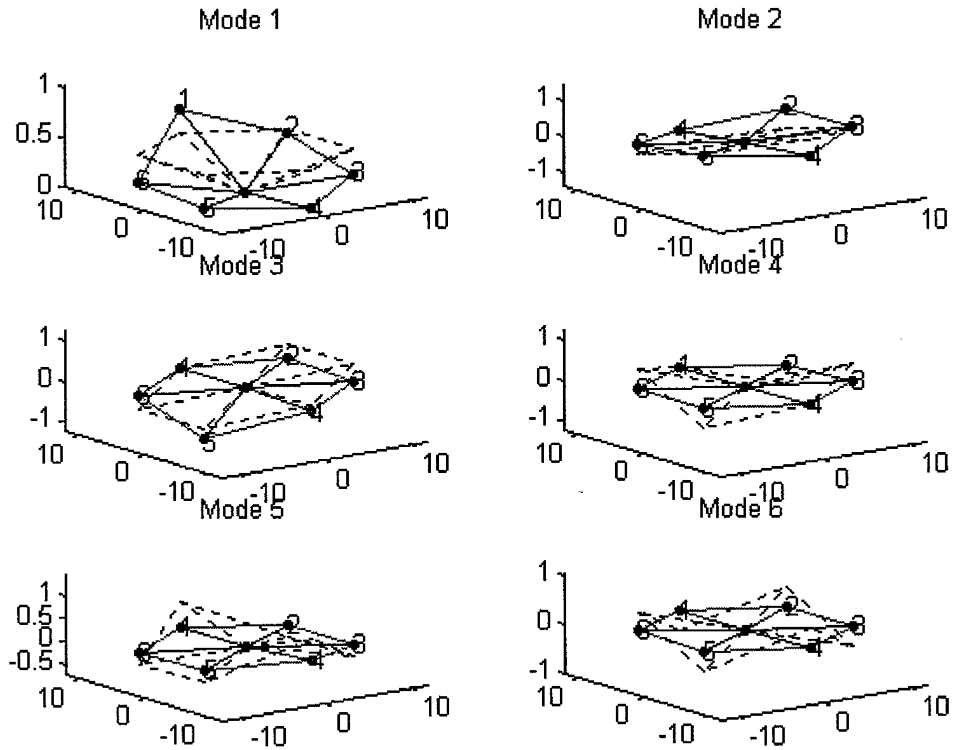
Mode 1	Mode2	Mode 3
0.0085 + 0.0047i	-0.0064 - 0.0320i	-0.0113 + 0.0123i
0.0323 + 0.0180i	-0.0088 - 0.0667i	0.0003 + 0.0003i
0.0467 + 0.0247i	0.0059 + 0.0322i	0.0094 - 0.0116i
0.0133 + 0.0071i	0.0016 + 0.0200i	-0.0323 + 0.0372i
0.0041 + 0.0023i	-0.0006 + 0.0071i	-0.0409 + 0.0445i
0.0020 + 0.0009i	-0.0019 - 0.0060i	-0.0134 + 0.0144i
Mode 4	**Mode 5**	**Mode 6**
0.0341 + 0.0787i	0.0263 + 0.0173i	-0.0124 - 0.0088i
-0.0158 - 0.0337i	-0.0052 - 0.0035i	0.0017 + 0.0012i
0.0057 + 0.0120i	-0.0073 - 0.0049i	-0.0005 - 0.0006i
-0.0103 - 0.0261i	0.0507 + 0.0346i	0.0037 + 0.0040i
-0.0031 - 0.0023i	-0.0505 - 0.0330i	-0.0127 - 0.0110i
0.0127 + 0.0308i	-0.0103 - 0.0070i	0.0430 + 0.0365i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 19

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.0225	0.3551	95.3344	0.5188	0.3483	0.0131
2	11.9587	0.4684	94.9861	0.7261	0.5585	**Modal Density**
3	12.5113	0.4807	96.7657	0.6908	0.6226	0.8490
4	13.1876	0.4984	99.0496	0.6065	0.5059	**File Name**
5	13.5643	0.3617	98.7481	0.8760	0.6606	analy_orange_19
6	14.9882	0.2844	92.0744	0.4421	0.2262	



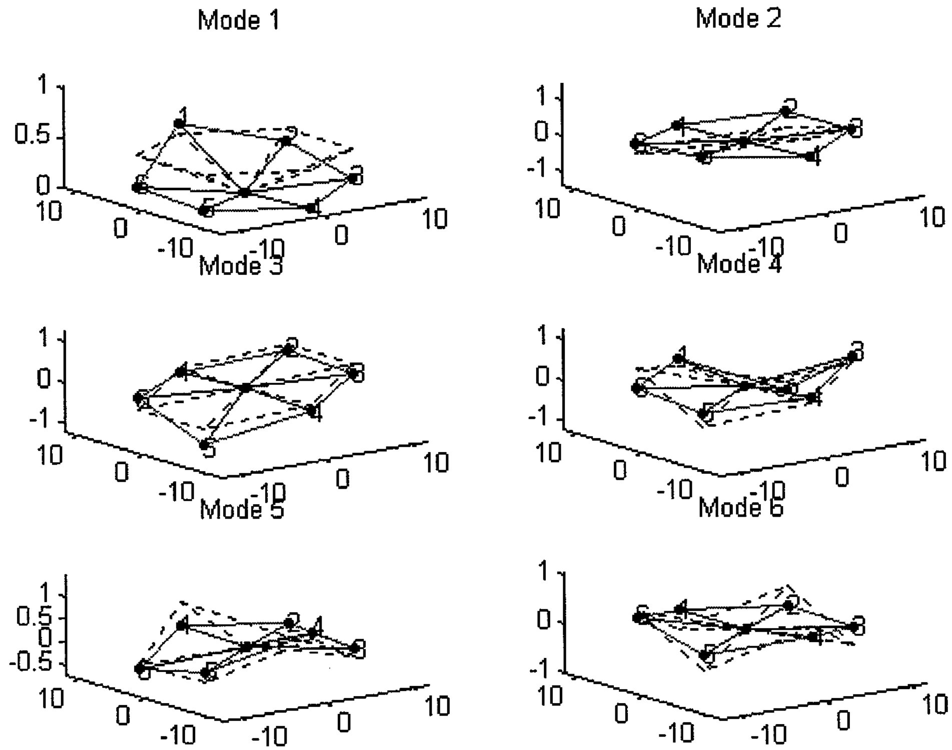
Mode 1	Mode2	Mode 3
0.0385 - 0.0321i	-0.0176 + 0.0299i	-0.0012 - 0.0059i
0.0225 - 0.0189i	0.0216 - 0.0359i	0.0118 + 0.0168i
0.0086 - 0.0075i	0.0237 - 0.0421i	0.0040 + 0.0107i
0.0023 - 0.0019i	0.0087 - 0.0132i	-0.0115 - 0.0072i
0.0043 - 0.0029i	0.0151 - 0.0176i	-0.0541 - 0.0427i
0.0076 - 0.0063i	-0.0011 + 0.0033i	-0.0105 - 0.0094i
Mode 4	**Mode 5**	**Mode 6**
0.0007 + 0.0178i	0.0005 + 0.0035i	-0.0002 - 0.0056i
-0.0021 - 0.0605i	-0.0001 + 0.0014i	0.0003 + 0.0021i
0.0022 + 0.0557i	-0.0007 - 0.0090i	-0.0002 - 0.0053i
0.0001 + 0.0136i	0.0069 + 0.0561i	0.0013 + 0.0316i
-0.0009 - 0.0136i	-0.0007 - 0.0048i	-0.0004 - 0.0119i
0.0001 + 0.0022i	-0.0029 - 0.0333i	0.0027 + 0.0497i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9329	0.4068	94.0386	0.4914	0.3117	0.0278
2	11.7212	0.3182	98.8399	0.9330	0.8984	**Modal Density**
3	11.8099	0.3976	98.0962	0.5488	0.3585	0.8631
4	12.6169	0.3384	97.8214	0.7133	0.5988	**File Name**
5	14.7085	0.2537	92.4924	0.6800	0.4285	analy_orange_20
6	14.9227	0.4798	94.5996	0.4980	0.3162	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 20

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



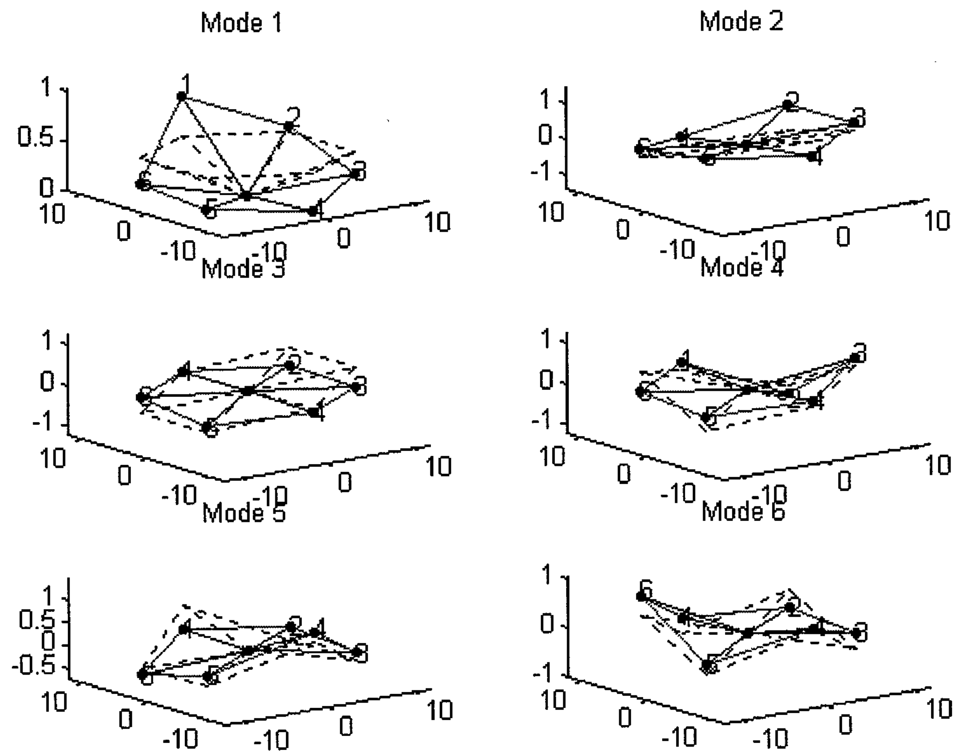
Mode 1	Mode2	Mode 3
0.0290 + 0.0389i	-0.0115 + 0.0311i	-0.0086 - 0.0026i
0.0171 + 0.0224i	0.0145 - 0.0402i	0.0264 + 0.0022i
0.0068 + 0.0087i	0.0160 - 0.0450i	0.0162 + 0.0026i
0.0018 + 0.0025i	0.0066 - 0.0139i	-0.0115 + 0.0019i
0.0032 + 0.0042i	0.0142 - 0.0174i	-0.0653 + 0.0057i
0.0056 + 0.0074i	0.0000 + 0.0039i	-0.0144 + 0.0006i
Mode 4	**Mode 5**	**Mode 6**
0.0169 - 0.0038i	0.0032 + 0.0023i	-0.0016 + 0.0054i
-0.0586 + 0.0122i	0.0013 + 0.0011i	0.0008 - 0.0023i
0.0546 - 0.0120i	-0.0078 - 0.0048i	-0.0015 + 0.0047i
0.0135 - 0.0026i	0.0485 + 0.0301i	0.0117 - 0.0289i
-0.0127 + 0.0030i	-0.0045 - 0.0016i	-0.0038 + 0.0112i
0.0018 - 0.0003i	-0.0255 - 0.0213i	0.0165 - 0.0477i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9160	0.4141	96.3194	0.4905	0.3105	0.0348
2	11.7190	0.3298	97.0427	0.9336	0.8840	**Modal Density**
3	11.8031	0.4248	98.0547	0.5753	0.4238	0.8677
4	12.6196	0.3353	99.0007	0.7171	0.5971	**File Name**
5	14.6961	0.2640	94.4181	0.6778	0.4255	analy_orange_20r1
6	14.9181	0.4908	91.2776	0.4934	0.3095	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 20

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



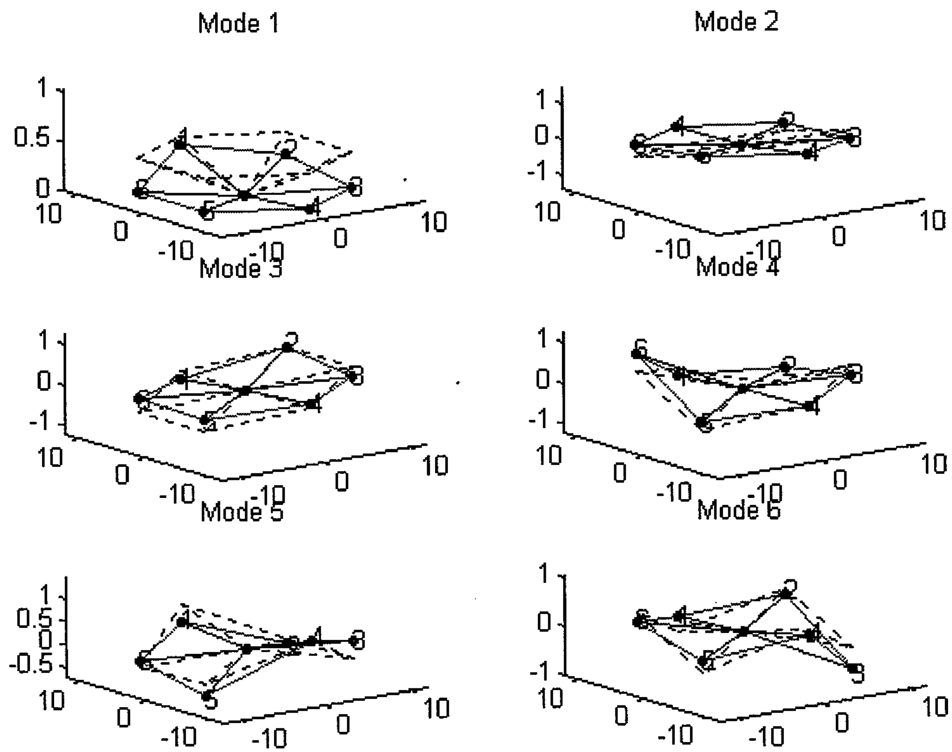
Mode 1	Mode2	Mode 3
0.0487 - 0.0115i	0.0004 - 0.0064i	0.0004 - 0.0064i
0.0283 - 0.0069i	0.0050 + 0.0220i	0.0050 + 0.0220i
0.0111 - 0.0032i	0.0008 + 0.0124i	0.0008 + 0.0124i
0.0029 - 0.0008i	-0.0059 - 0.0114i	-0.0059 - 0.0114i
0.0051 - 0.0010i	-0.0274 - 0.0629i	-0.0274 - 0.0629i
0.0095 - 0.0024i	-0.0052 - 0.0133i	-0.0052 - 0.0133i
Mode 4	**Mode 5**	**Mode 6**
0.0174 - 0.0009i	0.0033 + 0.0014i	-0.0056 - 0.0020i
-0.0600 + 0.0020i	0.0013 + 0.0009i	0.0019 + 0.0008i
0.0562 - 0.0021i	-0.0083 - 0.0039i	-0.0045 - 0.0021i
0.0138 - 0.0002i	0.0523 + 0.0237i	0.0270 + 0.0132i
-0.0128 + 0.0003i	-0.0046 - 0.0015i	-0.0111 - 0.0045i
0.0020 - 0.0002i	-0.0289 - 0.0152i	0.0478 + 0.0186i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 20

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9129	0.4945	97.3703	0.4908	0.3110	0.0409
2	11.7246	0.3168	98.9490	0.9374	0.8955	**Modal Density**
3	11.8065	0.3918	98.2076	0.5541	0.3711	0.8683
4	12.6180	0.3157	97.2157	0.7184	0.5962	**File Name**
5	14.6975	0.2808	95.9096	0.6734	0.4187	analy_orange_20r2
6	14.9165	0.4565	97.3507	0.4869	0.3009	



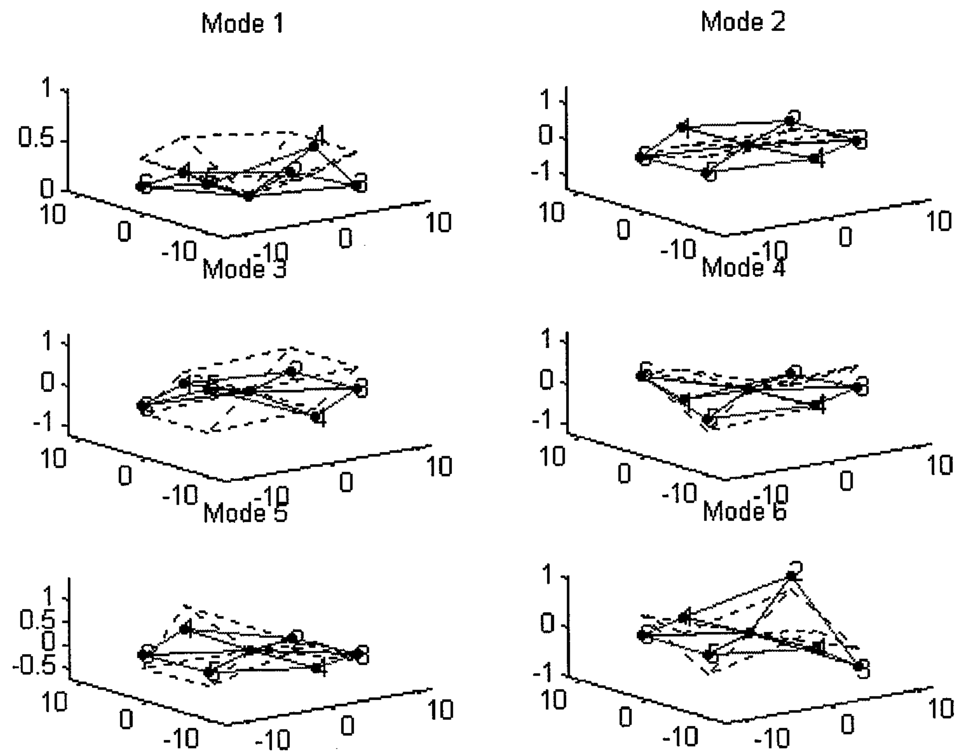
Mode 1	Mode2	Mode 3
0.0198 - 0.0455i	-0.0037 + 0.0116i	-0.0184 - 0.0211i
0.0116 - 0.0235i	-0.0016 + 0.0017i	0.0441 + 0.0519i
0.0031 - 0.0064i	0.0028 - 0.0088i	0.0187 + 0.0215i
0.0036 - 0.0063i	0.0158 - 0.0408i	0.0101 + 0.0128i
0.0041 - 0.0082i	0.0180 - 0.0415i	-0.0177 - 0.0196i
0.0046 - 0.0122i	0.0041 - 0.0070i	-0.0134 - 0.0162i
Mode 4	**Mode 5**	**Mode 6**
-0.0165 + 0.0026i	0.0140 + 0.0053i	-0.0082 - 0.0010i
-0.0028 - 0.0006i	-0.0260 - 0.0092i	0.0268 + 0.0028i
0.0224 - 0.0010i	0.0063 + 0.0029i	-0.0763 - 0.0093i
0.0019 - 0.0014i	0.0420 + 0.0185i	0.0257 + 0.0027i
-0.0279 + 0.0043i	-0.0391 - 0.0163i	-0.0130 - 0.0016i
0.0910 - 0.0113i	-0.0119 - 0.0056i	0.0229 + 0.0045i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9058	0.2780	94.9437	0.4872	0.3116	0.2485
2	11.4380	0.6004	95.6168	0.8337	0.5771	**Modal Density**
3	11.9351	0.4142	99.5148	0.6420	0.6208	0.5749
4	13.4122	0.4277	96.3550	0.5454	0.3491	**File Name**
5	12.3614	0.2318	98.7295	0.8991	0.7843	analy_orange_21
6	13.6860	0.3485	98.2909	0.4776	0.3009	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 21

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



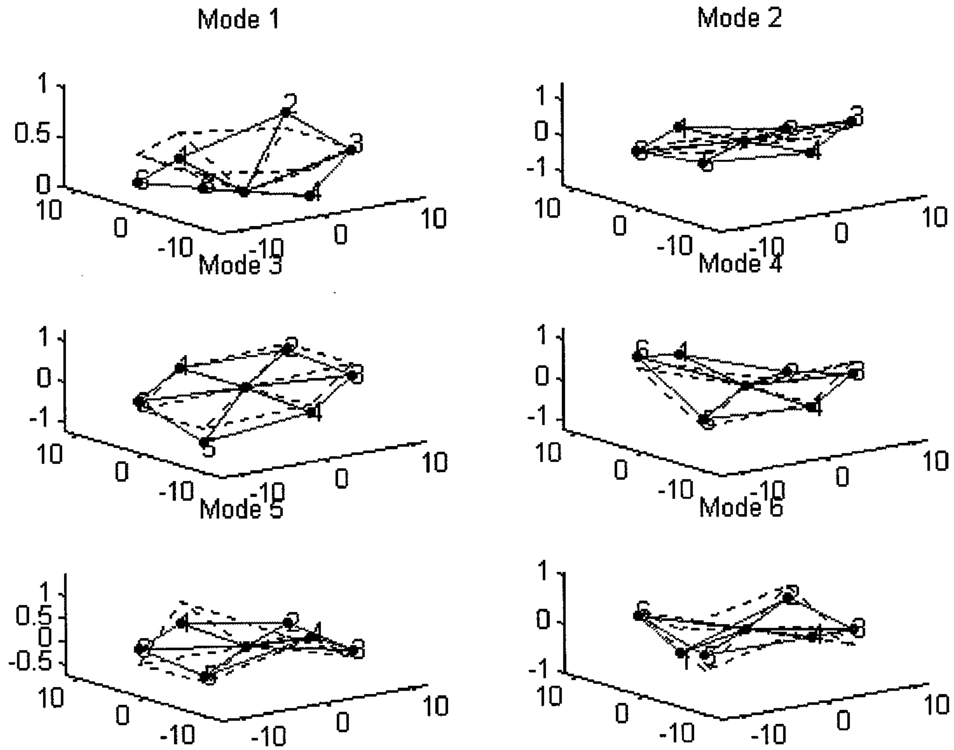
Mode 1	Mode2	Mode 3
0.0021 + 0.0017i	-0.0056 + 0.0181i	-0.0220 + 0.0189i
0.0006 + 0.0009i	-0.0009 + 0.0028i	-0.0051 + 0.0046i
0.0040 + 0.0031i	0.0008 - 0.0018i	-0.0028 + 0.0024i
0.0375 + 0.0280i	0.0067 - 0.0191i	-0.0126 + 0.0111i
0.0190 + 0.0141i	-0.0106 + 0.0256i	0.0399 - 0.0351i
0.0074 + 0.0061i	-0.0152 + 0.0442i	-0.0211 + 0.0190i
Mode 4	Mode 5	Mode 6
-0.0573 - 0.0285i	0.0037 - 0.0140i	-0.0045 + 0.0001i
-0.0156 - 0.0075i	-0.0194 + 0.0654i	0.0353 - 0.0003i
-0.0026 - 0.0010i	-0.0138 + 0.0482i	-0.0392 + 0.0007i
0.0035 + 0.0016i	0.0016 - 0.0046i	0.0030 - 0.0001i
-0.0142 - 0.0063i	0.0000 + 0.0004i	-0.0004 - 0.0002i
0.0318 + 0.0144i	-0.0005 + 0.0022i	0.0000 - 0.0003i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 22

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1674	0.2878	95.9859	0.4681	0.2699	0.0990
2	10.8762	0.4461	93.7146	0.7548	0.6159	**Modal Density**
3	11.5434	0.2041	98.7050	0.6528	0.6153	1.2895
4	12.1786	0.4018	98.1816	0.5989	0.4690	**File Name**
5	14.1806	0.3321	92.4749	0.7282	0.4892	analy_orange_22
6	15.3843	0.4546	80.0844	0.5517	0.3366	



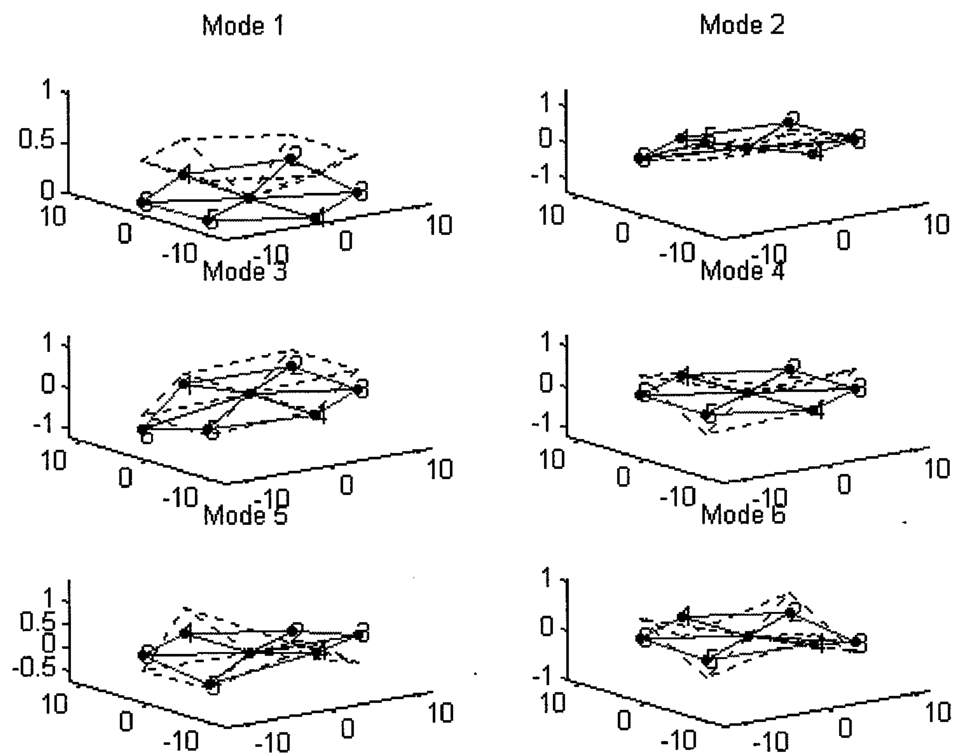
Mode 1	Mode2	Mode 3
0.0101 + 0.0084i	-0.0142 - 0.0152i	0.0005 + 0.0000i
0.0383 + 0.0298i	-0.0258 - 0.0273i	0.0216 + 0.0008i
0.0267 + 0.0208i	0.0334 + 0.0367i	0.0102 - 0.0002i
0.0113 + 0.0082i	0.0140 + 0.0128i	-0.0096 - 0.0020i
0.0178 + 0.0135i	0.0002 + 0.0003i	-0.0510 - 0.0037i
0.0092 + 0.0072i	-0.0151 - 0.0150i	-0.0178 - 0.0009i
Mode 4	**Mode 5**	**Mode 6**
0.0226 + 0.0069i	0.0072 + 0.0126i	-0.0840 + 0.0010i
-0.0198 - 0.0048i	0.0016 + 0.0002i	0.0167 - 0.0009i
0.0160 + 0.0033i	-0.0119 - 0.0123i	-0.0064 + 0.0003i
-0.0064 - 0.0020i	0.0566 + 0.0644i	0.0189 - 0.0008i
-0.0258 - 0.0065i	-0.0129 - 0.0137i	-0.0090 + 0.0005i
0.0653 + 0.0174i	0.0019 - 0.0005i	0.0313 - 0.0013i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 23

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.6952	0.2996	97.5890	0.5645	0.4697	0.2516
2	11.5906	0.4934	93.2585	0.8325	0.7641	**Modal Density**
3	10.9433	0.3176	91.8712	0.5865	0.4511	0.5917
4	12.0503	0.3018	97.9974	0.5992	0.4907	**File Name**
5	13.2041	0.4589	97.1889	0.6104	0.3109	analy_orange_23
6	13.4931	0.5697	98.7830	0.4557	0.2529	



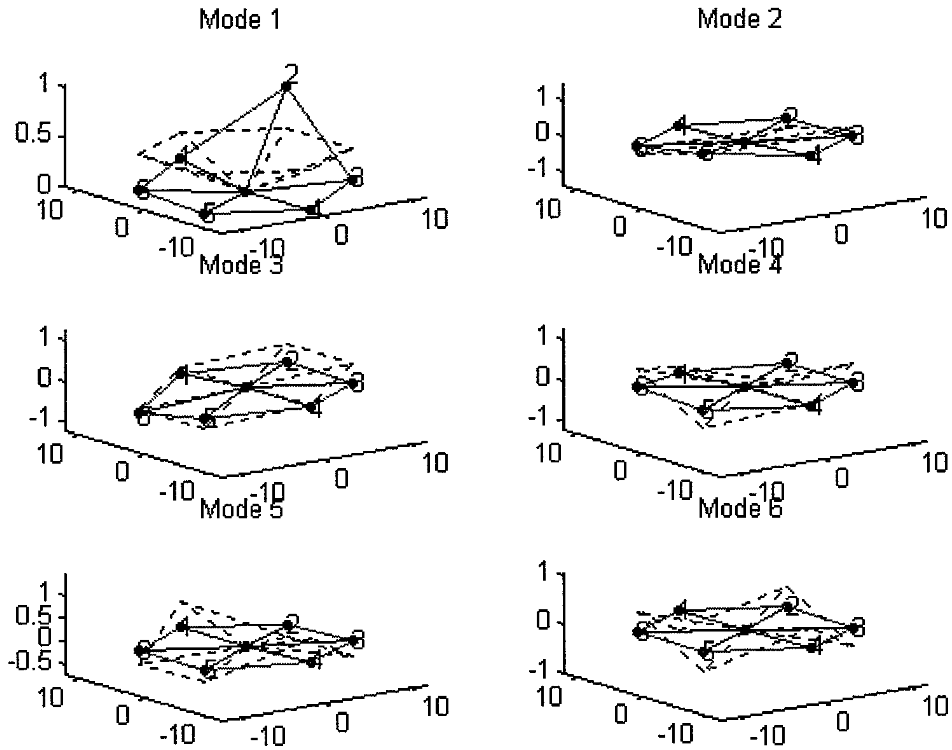
Mode 1	Mode2	Mode 3
0.0023 - 0.0100i	-0.0343 + 0.0105i	-0.0192 + 0.0068i
0.0099 - 0.0544i	0.0037 - 0.0011i	0.0059 - 0.0022i
0.0013 - 0.0067i	0.0102 - 0.0034i	0.0001 - 0.0003i
0.0004 - 0.0008i	0.0369 - 0.0120i	-0.0056 + 0.0014i
0.0003 - 0.0006i	0.0849 - 0.0271i	-0.0251 + 0.0079i
0.0003 - 0.0030i	-0.0207 + 0.0068i	-0.0623 + 0.0227i
Mode 4	**Mode 5**	**Mode 6**
-0.0077 + 0.0833i	0.0005 - 0.0007i	0.0000 + 0.0007i
0.0010 - 0.0105i	-0.0025 + 0.0039i	0.0009 - 0.0029i
0.0001 + 0.0008i	0.0248 - 0.0374i	-0.0105 + 0.0348i
-0.0006 + 0.0139i	0.0309 - 0.0447i	0.0096 - 0.0320i
-0.0006 + 0.0246i	-0.0147 + 0.0229i	-0.0025 + 0.0083i
0.0025 - 0.0336i	0.0023 - 0.0042i	0.0000 - 0.0012i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 24

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2851	0.3963	89.9995	0.4190	0.1846	0.0596
2	12.9583	0.4583	98.3409	0.6897	0.4778	**Modal Density**
3	11.7301	0.4093	92.6791	0.5632	0.3891	1.2276
4	13.4426	0.3122	94.9087	0.5683	0.4032	**File Name**
5	14.3266	0.3294	88.8914	0.8056	0.6208	analy_orange_24
6	15.3505	0.2436	91.1637	0.5643	0.3541	



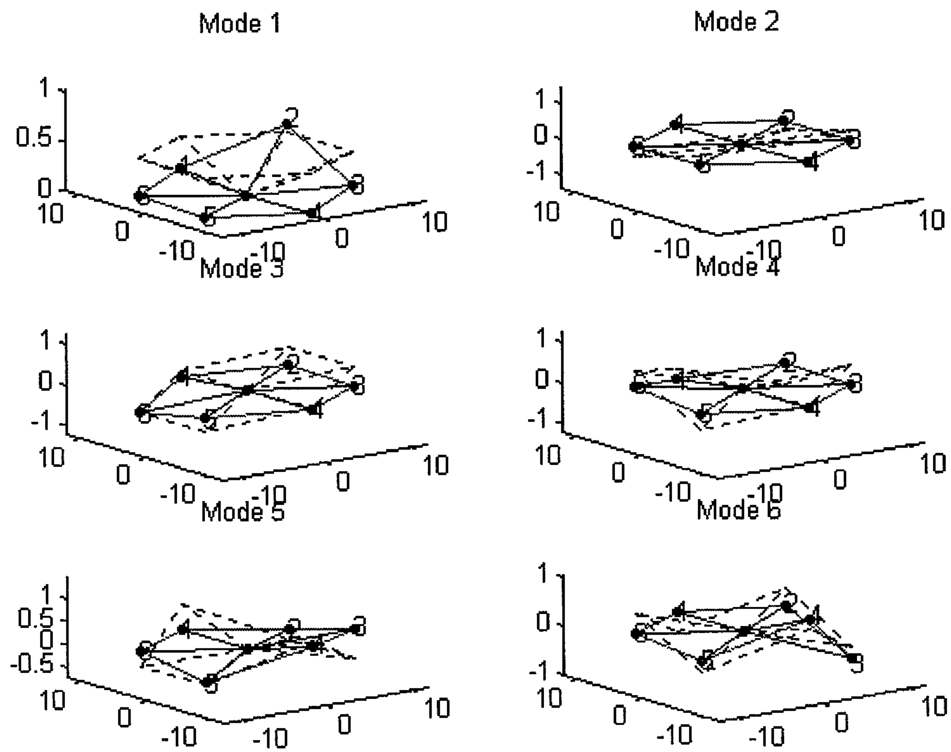
Mode 1	Mode2	Mode 3
0.0084 + 0.0050i	-0.0124 - 0.0348i	-0.0128 + 0.0157i
0.0467 + 0.0297i	0.0013 + 0.0036i	0.0036 - 0.0046i
0.0056 + 0.0035i	0.0038 + 0.0103i	0.0001 - 0.0002i
0.0009 + 0.0003i	0.0139 + 0.0362i	-0.0039 + 0.0040i
0.0004 - 0.0000i	0.0316 + 0.0836i	-0.0173 + 0.0187i
0.0027 + 0.0009i	-0.0075 - 0.0194i	-0.0424 + 0.0501i
Mode 4	Mode 5	Mode 6
-0.0164 + 0.0810i	0.0010 - 0.0005i	-0.0005 - 0.0008i
0.0021 - 0.0102i	-0.0003 + 0.0047i	0.0002 + 0.0030i
0.0001 + 0.0010i	0.0050 - 0.0441i	-0.0019 - 0.0367i
-0.0021 + 0.0141i	0.0067 - 0.0537i	0.0014 + 0.0326i
-0.0029 + 0.0248i	-0.0019 + 0.0277i	-0.0007 - 0.0085i
0.0060 - 0.0329i	0.0002 - 0.0050i	0.0003 + 0.0010i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 24

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2992	0.3957	86.3977	0.4181	0.1831	0.0553
2	12.9749	0.4600	99.4078	0.6902	0.4783	**Modal Density**
3	11.7317	0.4247	98.1973	0.5615	0.3853	1.2250
4	13.4464	0.2997	97.4436	0.5703	0.4083	**File Name**
5	14.3412	0.3450	89.1473	0.8071	0.6265	analy_orange_24r1
6	15.3625	0.2833	89.3392	0.5556	0.3514	



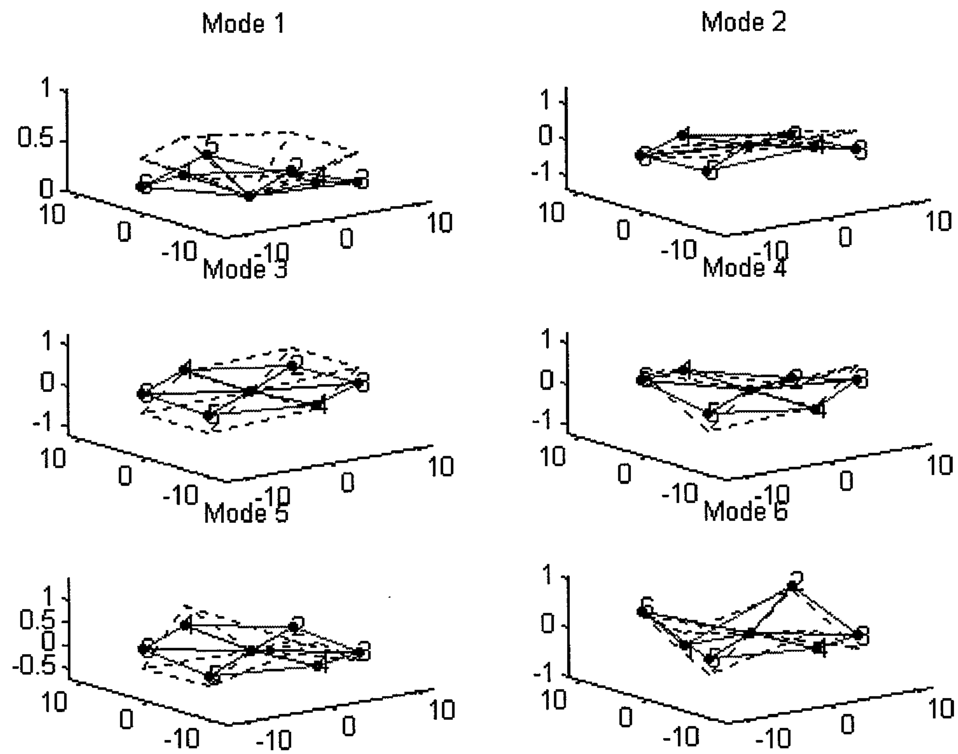
Mode 1	Mode2	Mode 3
0.0051 - 0.0087i	-0.0021 - 0.0362i	-0.0112 - 0.0175i
0.0271 - 0.0475i	0.0001 + 0.0034i	0.0034 + 0.0058i
0.0037 - 0.0064i	0.0006 + 0.0116i	0.0004 + 0.0003i
0.0008 - 0.0009i	0.0022 + 0.0394i	-0.0022 - 0.0049i
0.0006 - 0.0006i	0.0042 + 0.0889i	-0.0117 - 0.0223i
0.0016 - 0.0029i	-0.0008 - 0.0208i	-0.0339 - 0.0560i
Mode 4	Mode 5	Mode 6
-0.0242 - 0.0786i	0.0004 - 0.0003i	-0.0004 + 0.0004i
0.0031 + 0.0102i	-0.0031 + 0.0040i	0.0031 - 0.0014i
-0.0002 - 0.0004i	0.0269 - 0.0350i	-0.0323 + 0.0154i
-0.0046 - 0.0133i	0.0341 - 0.0420i	0.0295 - 0.0137i
-0.0086 - 0.0227i	-0.0169 + 0.0223i	-0.0072 + 0.0036i
0.0107 + 0.0324i	0.0029 - 0.0042i	0.0010 - 0.0006i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 24

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.3104	0.3526	72.2128	0.4197	0.1859	0.0636
2	12.9819	0.4479	97.7722	0.6917	0.4816	**Modal Density**
3	11.7281	0.3773	95.6469	0.5625	0.3881	1.2317
4	13.4827	0.2874	95.7248	0.5712	0.4100	**File Name**
5	14.3413	0.3488	95.9503	0.8064	0.6280	analy_orange_24r2
6	15.4026	0.3462	88.7971	0.5616	0.3526	



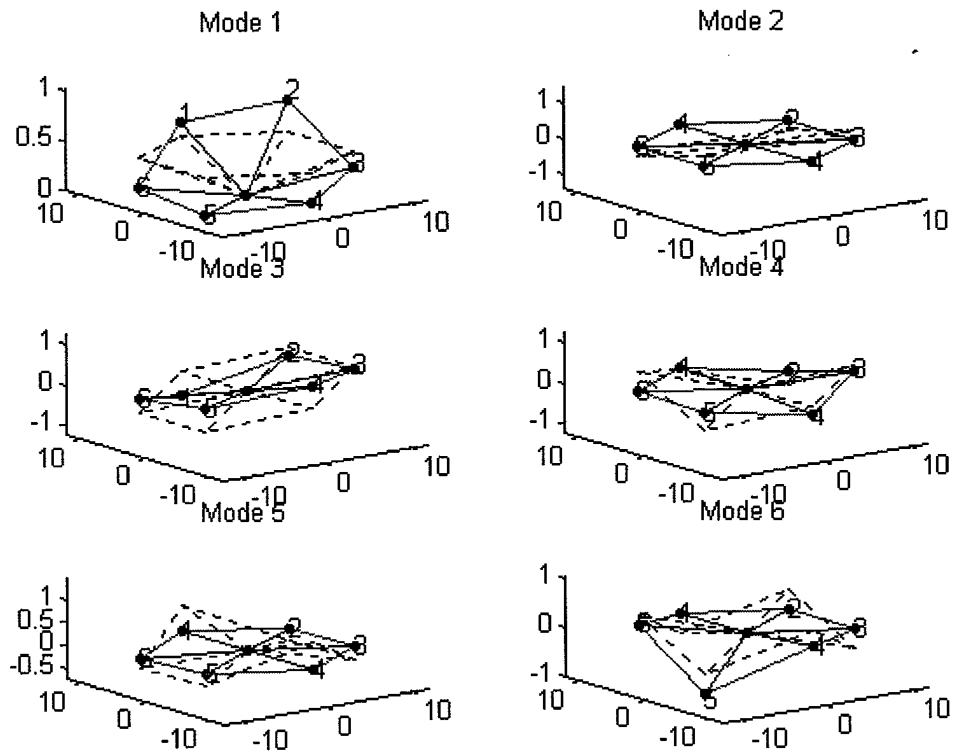
Mode 1	Mode2	Mode 3
-0.0253 + 0.0215i	0.0020 - 0.0022i	0.0013 - 0.0054i
-0.0313 + 0.0255i	0.0027 - 0.0022i	0.0034 - 0.0237i
-0.0186 + 0.0157i	0.0067 - 0.0056i	0.0068 - 0.0495i
0.0364 - 0.0301i	0.0206 - 0.0179i	0.0069 - 0.0415i
-0.0084 + 0.0068i	0.0390 - 0.0338i	-0.0037 + 0.0301i
-0.0182 + 0.0157i	0.0079 - 0.0073i	-0.0003 + 0.0069i
Mode 4	Mode 5	Mode 6
-0.0008 + 0.0036i	0.0119 + 0.0551i	-0.0586 - 0.0148i
-0.0310 + 0.0647i	0.0027 + 0.0158i	0.0427 + 0.0109i
0.0127 - 0.0283i	-0.0091 - 0.0395i	-0.0113 - 0.0026i
-0.0024 + 0.0060i	0.0085 + 0.0338i	0.0043 + 0.0011i
-0.0052 + 0.0110i	-0.0051 - 0.0196i	-0.0067 - 0.0018i
0.0312 - 0.0660i	0.0093 + 0.0399i	0.0435 + 0.0117i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 25

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.8526	0.4508	95.1546	0.4760	0.2851	0.1000
2	12.2329	0.4592	99.3179	0.9668	1.0238	**Modal Density**
3	11.6821	0.4328	98.3112	0.7652	0.8095	0.6443
4	13.2518	0.3439	98.6544	0.7389	0.6067	**File Name**
5	12.6886	0.2893	99.5591	0.9380	1.0135	analy_orange_25
6	13.9164	0.3348	98.0964	0.5976	0.4803	



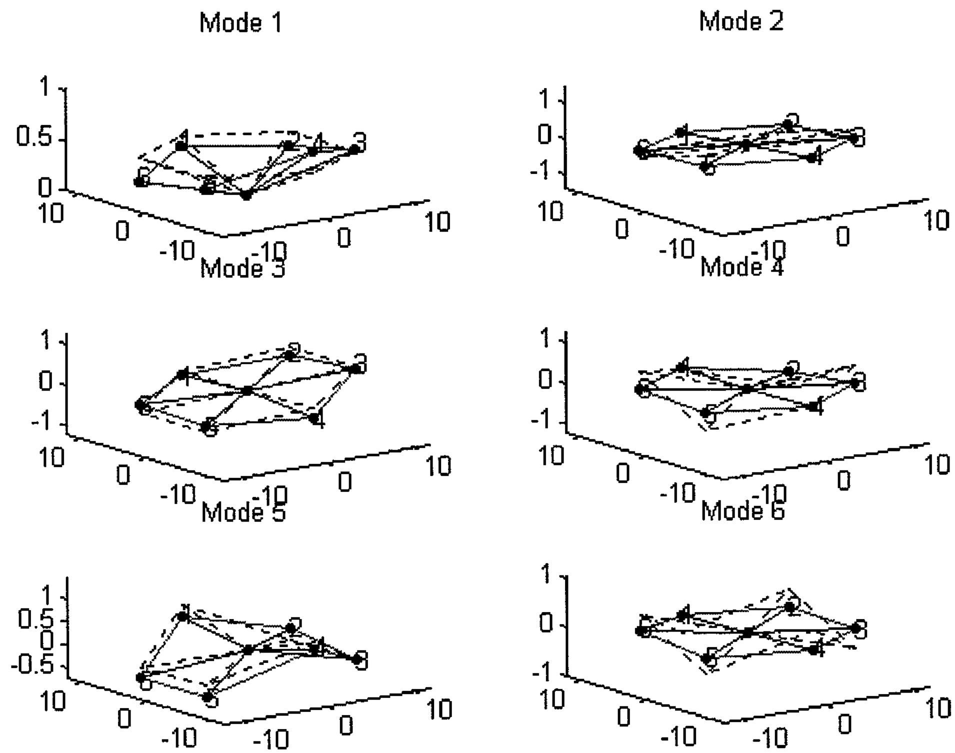
Mode 1	Mode2	Mode 3
0.0313 - 0.0101i	-0.0014 - 0.0231i	-0.0411 - 0.0077i
0.0415 - 0.0121i	0.0003 + 0.0282i	0.0186 + 0.0041i
0.0144 - 0.0042i	0.0011 - 0.0069i	0.0292 + 0.0058i
0.0066 - 0.0020i	0.0012 - 0.0406i	0.0353 + 0.0068i
0.0018 - 0.0007i	0.0002 - 0.0085i	0.0046 + 0.0005i
0.0061 - 0.0028i	0.0008 - 0.0076i	-0.0092 - 0.0015i
Mode 4	Mode 5	Mode 6
0.0032 + 0.0068i	0.0009 - 0.0149i	-0.0008 + 0.0008i
-0.0103 - 0.0212i	0.0000 + 0.0020i	0.0005 - 0.0002i
0.0246 + 0.0516i	0.0000 + 0.0009i	-0.0005 + 0.0002i
-0.0136 - 0.0298i	0.0007 - 0.0068i	0.0058 - 0.0034i
-0.0030 - 0.0067i	-0.0029 + 0.0317i	-0.0515 + 0.0323i
0.0001 + 0.0010i	-0.0077 + 0.0929i	0.0130 - 0.0101i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9775	0.4102	95.2619	0.5405	0.3786	0.0482
2	10.9188	0.2895	96.5244	0.7980	0.6818	**Modal Density**
3	10.6601	0.3315	98.2823	0.7928	0.8551	1.2171
4	11.6989	0.3127	94.2570	0.6190	0.5163	**File Name**
5	13.0727	0.5429	94.3364	0.6187	0.3250	analy_orange_26
6	14.8565	0.2691	66.8173	0.4254	0.1955	

System Information
System: Orange Band (34.13N/m)
PZT Coupling: Off
Mistuning: Set 26

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



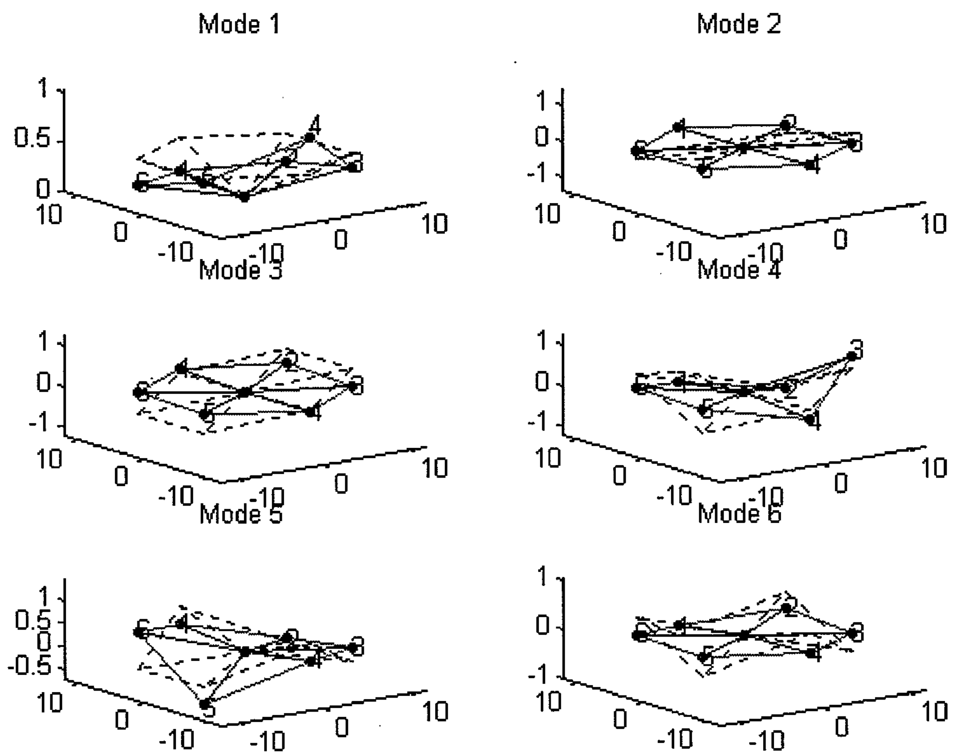
Mode 1	Mode2	Mode 3
0.0203 + 0.0074i	-0.0149 + 0.0435i	-0.0091 - 0.0083i
0.0182 + 0.0068i	-0.0052 + 0.0170i	0.0210 + 0.0188i
0.0278 + 0.0103i	0.0031 - 0.0052i	0.0326 + 0.0293i
0.0409 + 0.0162i	0.0083 - 0.0266i	-0.0169 - 0.0146i
0.0190 + 0.0079i	0.0010 - 0.0055i	-0.0256 - 0.0221i
0.0120 + 0.0044i	-0.0056 + 0.0151i	-0.0196 - 0.0172i
Mode 4	Mode 5	Mode 6
0.0027 + 0.0160i	0.0245 + 0.0104i	-0.0034 + 0.0235i
-0.0104 - 0.0627i	0.0003 + 0.0002i	0.0034 - 0.0286i
0.0046 + 0.0260i	-0.0221 - 0.0092i	-0.0019 + 0.0138i
0.0007 + 0.0007i	0.0335 + 0.0146i	0.0027 - 0.0173i
-0.0056 - 0.0287i	-0.0428 - 0.0194i	-0.0076 + 0.0490i
0.0042 + 0.0202i	-0.0436 - 0.0193i	0.0088 - 0.0543i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 27

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.6380	0.4465	95.2619	0.6046	0.5907	0.5997
2	10.9329	0.2473	96.5244	0.7472	0.5972	**Modal Density**
3	11.3201	0.2980	98.2823	0.8223	1.0592	0.4041
4	12.2788	0.3081	94.2570	0.6234	0.5544	**File Name**
5	11.9112	0.3236	94.3364	1.0205	0.9962	analy_orange_27
6	12.6056	0.2939	66.8173	0.6371	0.5550	



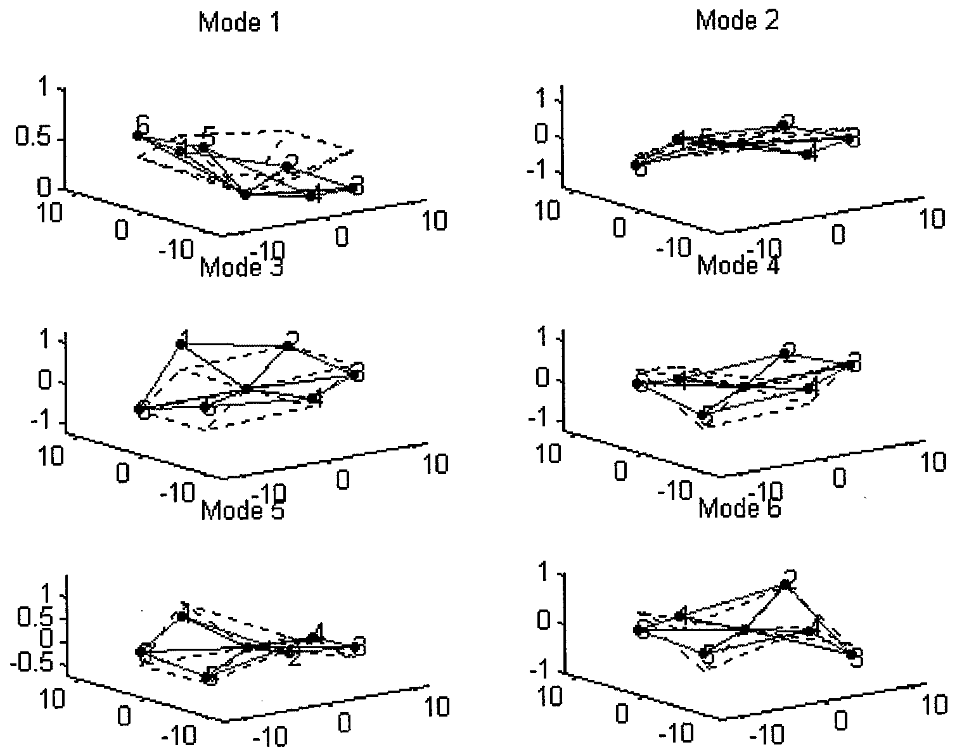
Mode 1	Mode2	Mode 3
0.0036 + 0.0010i	-0.0027 + 0.0210i	0.0042 + 0.0118i
0.0078 + 0.0022i	-0.0037 + 0.0551i	0.0093 - 0.0147i
0.0146 + 0.0042i	-0.0012 + 0.0256i	0.0029 - 0.0204i
0.0439 + 0.0147i	0.0015 - 0.0179i	-0.0035 - 0.0147i
0.0204 + 0.0073i	-0.0014 - 0.0059i	0.0008 + 0.0389i
0.0082 + 0.0029i	-0.0023 + 0.0131i	0.0047 + 0.0502i
Mode 4	**Mode 5**	**Mode 6**
-0.0206 - 0.0012i	0.0129 - 0.0068i	-0.0200 + 0.0838i
-0.0386 + 0.0007i	-0.0144 + 0.0083i	0.0062 - 0.0287i
0.0638 - 0.0002i	0.0014 - 0.0002i	-0.0024 + 0.0104i
-0.0198 + 0.0003i	0.0153 - 0.0091i	0.0005 - 0.0032i
0.0063 - 0.0012i	-0.0503 + 0.0286i	-0.0017 + 0.0094i
0.0134 + 0.0010i	0.0373 - 0.0210i	0.0058 - 0.0285i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.7737	0.3448	97.0987	0.4830	0.3076	0.0117
2	11.5310	0.3153	98.2852	0.7163	0.5471	**Modal Density**
3	11.6134	0.4357	98.2631	0.7131	0.7339	0.5721
4	12.5658	0.3080	98.5677	0.6367	0.5683	**File Name**
5	12.4363	0.2641	97.9955	0.7724	0.6068	analy_orange_28
6	13.5083	0.4782	97.4194	0.4581	0.2573	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 28

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



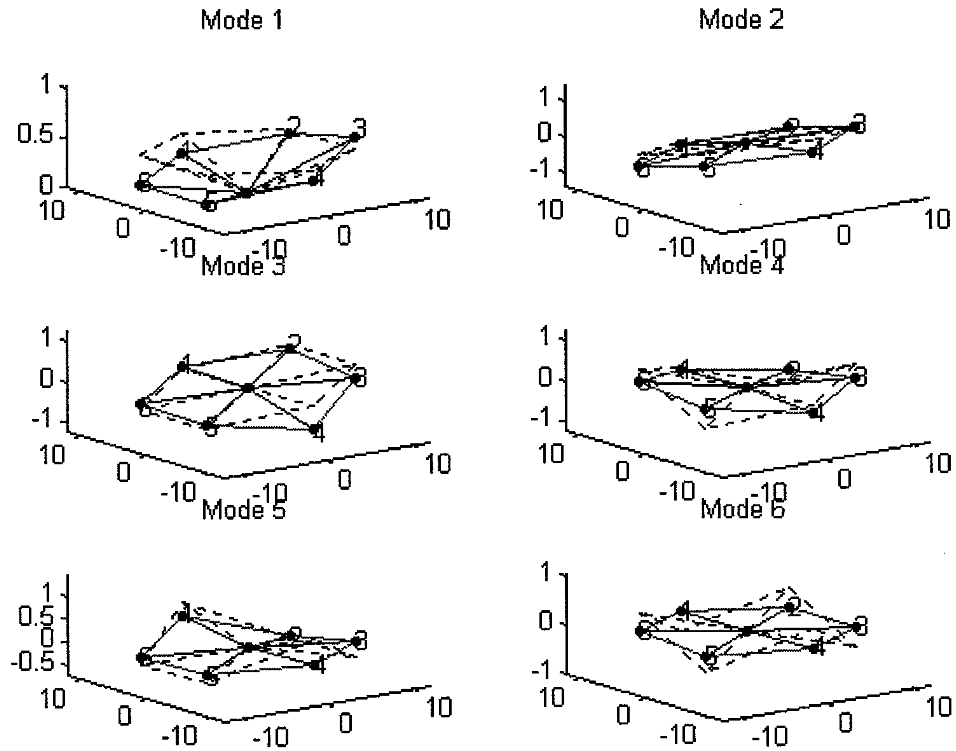
Mode 1	Mode2	Mode 3
0.0156 - 0.0019i	-0.0312 + 0.0066i	0.0531 - 0.0154i
0.0042 - 0.0006i	-0.0097 + 0.0012i	0.0427 - 0.0131i
0.0027 - 0.0003i	0.0006 - 0.0009i	0.0217 - 0.0061i
0.0118 - 0.0012i	0.0140 - 0.0034i	0.0164 - 0.0044i
0.0460 - 0.0044i	0.0446 - 0.0105i	0.0077 - 0.0028i
0.0413 - 0.0051i	-0.0381 + 0.0097i	-0.0361 + 0.0105i
Mode 4	**Mode 5**	**Mode 6**
-0.0278 - 0.0264i	0.0253 - 0.0118i	-0.0090 - 0.0056i
0.0214 + 0.0219i	-0.0590 + 0.0265i	0.0362 + 0.0228i
0.0376 + 0.0368i	-0.0075 + 0.0042i	-0.0491 - 0.0316i
0.0354 + 0.0354i	0.0636 - 0.0282i	0.0281 + 0.0193i
-0.0146 - 0.0133i	-0.0133 + 0.0061i	-0.0048 - 0.0029i
0.0132 + 0.0122i	-0.0030 + 0.0019i	0.0023 + 0.0014i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 29

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.7031	0.3491	97.6270	0.5776	0.3994	0.1035
2	11.3662	0.2802	93.7542	0.8878	0.7822	**Modal Density**
3	12.0409	0.3231	98.7404	0.7742	0.8575	0.7099
4	12.6652	0.4400	99.1603	0.8705	1.0222	**File Name**
5	13.1835	0.3438	98.1936	0.8348	0.6140	analy_orange_29
6	13.9956	0.2825	97.0979	0.5659	0.4379	



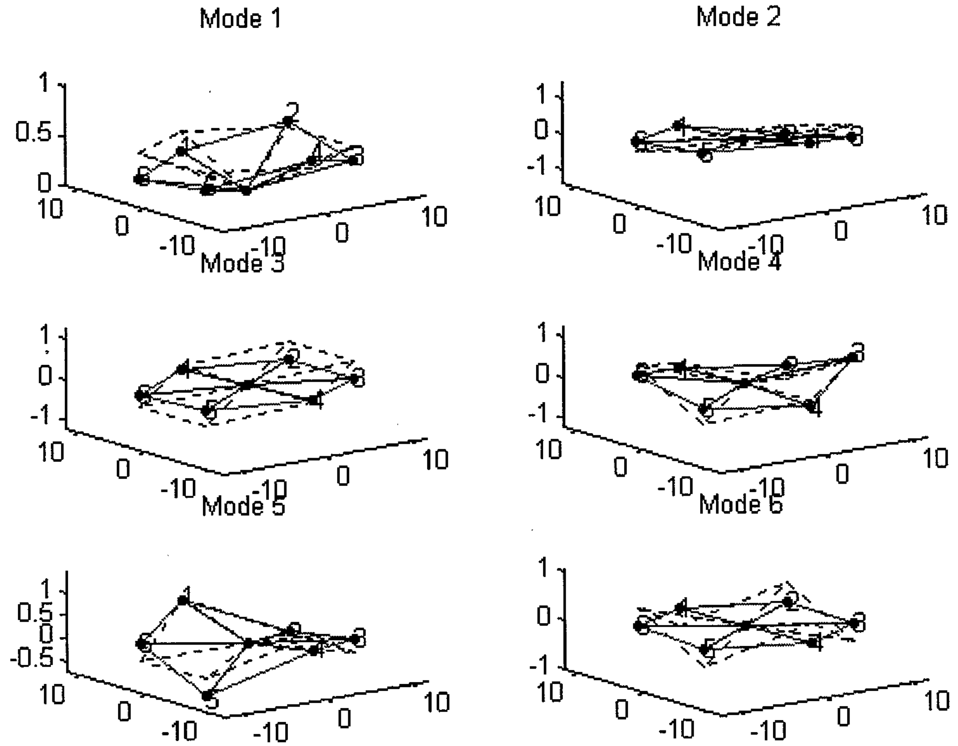
Mode 1	Mode2	Mode 3
0.0126 + 0.0110i	-0.0445 - 0.0041i	0.0043 + 0.0013i
0.0239 + 0.0203i	-0.0164 + 0.0000i	0.0318 + 0.0161i
0.0341 + 0.0290i	0.0232 + 0.0038i	0.0099 + 0.0052i
0.0201 + 0.0160i	0.0172 + 0.0003i	-0.0449 - 0.0229i
0.0071 + 0.0050i	-0.0061 - 0.0019i	-0.0283 - 0.0128i
0.0077 + 0.0068i	-0.0415 - 0.0050i	-0.0276 - 0.0149i
Mode 4	Mode 5	Mode 6
-0.0044 + 0.0132i	0.0254 - 0.0565i	-0.0014 - 0.0122i
-0.0123 + 0.0343i	-0.0202 + 0.0471i	0.0009 + 0.0061i
0.0106 - 0.0310i	0.0052 - 0.0133i	-0.0008 - 0.0063i
-0.0131 + 0.0361i	0.0035 - 0.0066i	0.0029 + 0.0289i
-0.0009 + 0.0024i	-0.0103 + 0.0247i	-0.0077 - 0.0888i
0.0137 - 0.0382i	-0.0127 + 0.0278i	0.0032 + 0.0307i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 30

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9121	0.4464	96.8591	0.5849	0.5107	0.3504
2	11.4644	0.4002	96.8372	0.9049	0.7997	**Modal Density**
3	11.7305	0.3819	98.3151	0.7626	0.8736	0.5248
4	12.2819	0.3368	97.4206	0.9324	1.0448	**File Name**
5	12.7043	0.2784	99.1503	0.8532	0.7609	analy_orange_30
6	13.4745	0.3735	98.1099	0.4574	0.2559	



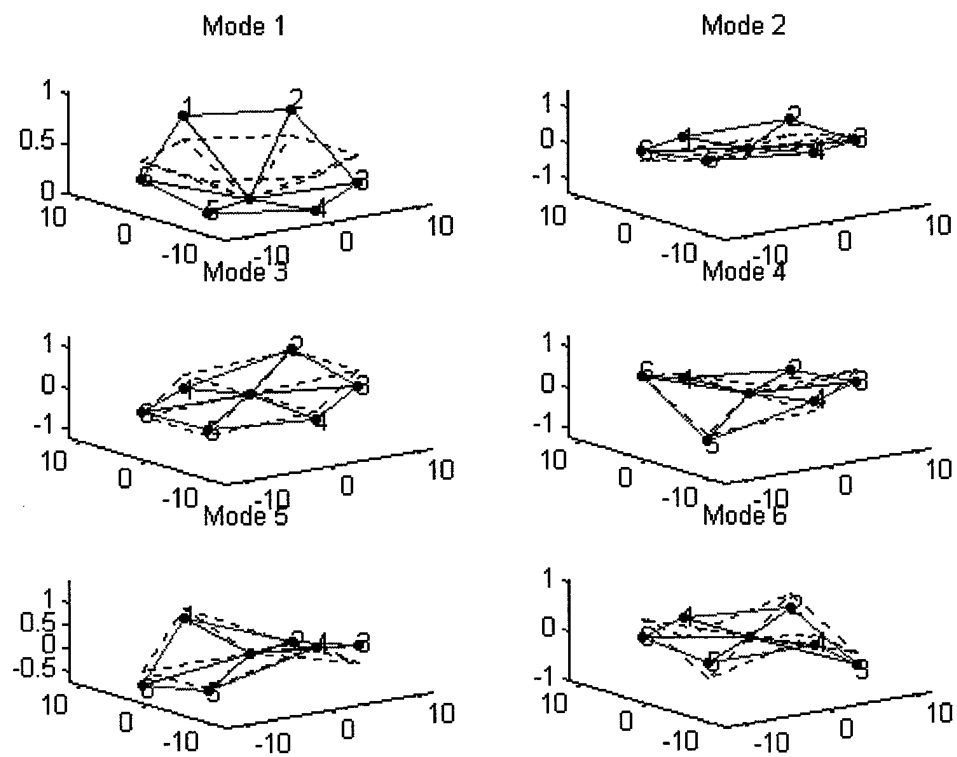
Mode 1	Mode2	Mode 3
0.0140 - 0.0098i	-0.0124 - 0.0112i	-0.0073 + 0.0296i
0.0314 - 0.0225i	-0.0302 - 0.0269i	0.0036 - 0.0138i
0.0174 - 0.0125i	-0.0023 - 0.0013i	0.0035 - 0.0159i
0.0328 - 0.0225i	0.0263 + 0.0262i	0.0038 - 0.0133i
0.0158 - 0.0111i	0.0125 + 0.0120i	-0.0073 + 0.0288i
0.0104 - 0.0074i	-0.0011 - 0.0003i	-0.0119 + 0.0491i
Mode 4	**Mode 5**	**Mode 6**
-0.0098 - 0.0117i	0.0406 + 0.0200i	-0.0040 - 0.0487i
-0.0126 - 0.0140i	-0.0170 - 0.0081i	0.0018 + 0.0222i
0.0421 + 0.0487i	0.0003 + 0.0003i	-0.0029 - 0.0307i
-0.0109 - 0.0126i	0.0192 + 0.0091i	0.0012 + 0.0178i
-0.0071 - 0.0076i	-0.0496 - 0.0245i	-0.0033 - 0.0395i
0.0198 + 0.0229i	0.0040 + 0.0024i	0.0038 + 0.0542i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.6934	0.3495	99.1506	0.6780	0.6109	0.3219
2	10.9637	0.3974	95.7712	0.8563	0.6837	**Modal Density**
3	11.5227	0.3494	98.5316	0.7016	0.7599	0.4362
4	12.4769	0.3249	98.8600	0.6034	0.4979	**File Name**
5	12.2250	0.2750	96.1106	0.8042	0.6346	analy_orange_31
6	12.8149	0.2814	99.4861	0.6996	0.6916	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 31

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



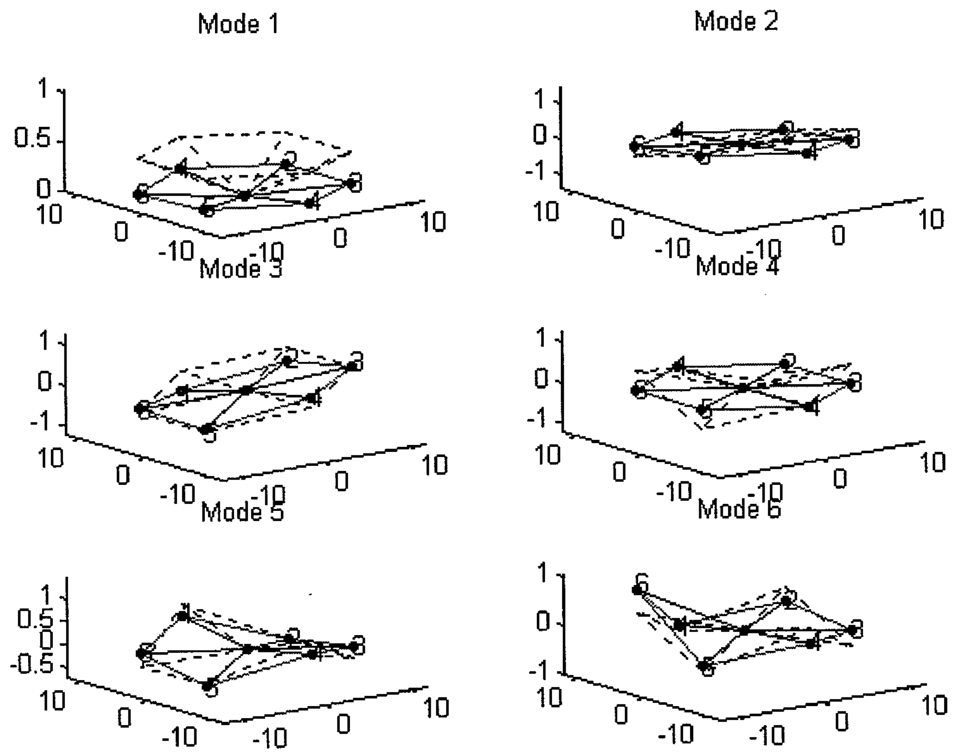
Mode 1	Mode2	Mode 3
0.0430 - 0.0111i	-0.0167 + 0.0208i	-0.0263 + 0.0178i
0.0453 - 0.0116i	0.0114 - 0.0119i	0.0388 - 0.0266i
0.0088 - 0.0028i	0.0076 - 0.0109i	0.0063 - 0.0056i
0.0054 - 0.0019i	0.0257 - 0.0355i	-0.0149 + 0.0059i
0.0061 - 0.0022i	0.0188 - 0.0265i	-0.0252 + 0.0152i
0.0152 - 0.0042i	-0.0003 - 0.0010i	-0.0290 + 0.0205i
Mode 4	Mode 5	Mode 6
-0.0118 - 0.0063i	0.0288 + 0.0054i	-0.0025 - 0.0024i
-0.0015 - 0.0008i	-0.0170 - 0.0033i	0.0126 + 0.0123i
0.0150 + 0.0088i	0.0090 + 0.0021i	-0.0608 - 0.0609i
0.0252 + 0.0134i	0.0456 + 0.0090i	0.0192 + 0.0192i
-0.0569 - 0.0294i	-0.0257 - 0.0050i	-0.0073 - 0.0071i
0.0465 + 0.0250i	-0.0505 - 0.0099i	0.0026 + 0.0029i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 32

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.5848	0.3787	97.4674	0.5903	0.3980	0.1748
2	11.4285	0.4471	95.1730	0.8479	0.7913	**Modal Density**
3	11.3065	0.2553	99.1150	0.8008	0.9675	0.6446
4	12.6751	0.2925	99.1625	0.7064	0.6606	**File Name**
5	12.1046	0.2912	98.7676	0.9208	0.8736	analy_orange_32
6	13.5743	0.4226	96.3742	0.4396	0.2214	



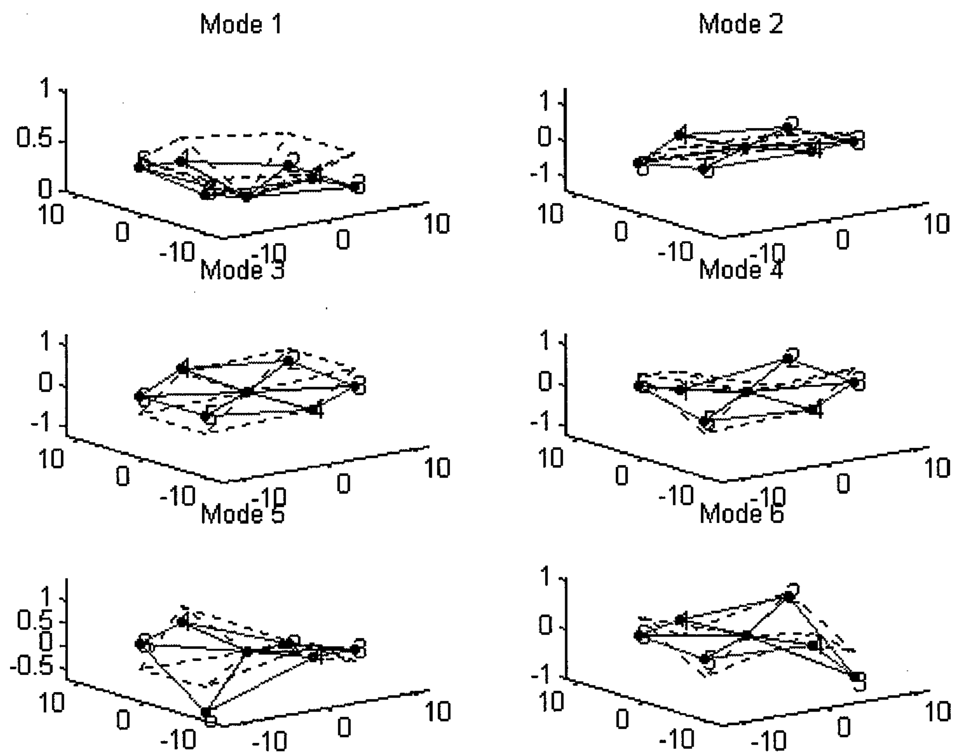
Mode 1	Mode2	Mode 3
0.0060 + 0.0250i	-0.0146 + 0.0259i	-0.0434 + 0.0118i
0.0080 + 0.0363i	-0.0184 + 0.0320i	0.0143 - 0.0028i
0.0063 + 0.0300i	-0.0019 + 0.0037i	0.0409 - 0.0110i
0.0090 + 0.0403i	0.0160 - 0.0289i	0.0207 - 0.0051i
0.0077 + 0.0317i	0.0175 - 0.0283i	-0.0390 + 0.0107i
0.0036 + 0.0141i	0.0007 + 0.0005i	-0.0304 + 0.0077i
Mode 4	**Mode 5**	**Mode 6**
0.0010 - 0.0136i	0.0212 - 0.0309i	-0.0301 + 0.0066i
-0.0015 + 0.0484i	-0.0186 + 0.0257i	0.0114 - 0.0029i
0.0015 - 0.0623i	-0.0018 + 0.0047i	-0.0064 + 0.0020i
-0.0016 + 0.0370i	0.0208 - 0.0312i	0.0098 - 0.0025i
0.0008 - 0.0078i	-0.0231 + 0.0340i	-0.0277 + 0.0062i
0.0002 - 0.0276i	0.0005 - 0.0001i	0.0868 - 0.0177i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.1919	0.2862	98.8366	0.7635	0.8104	0.1943
2	11.5149	0.4012	95.4056	1.0468	0.9855	**Modal Density**
3	11.8988	0.2920	99.0766	0.9363	1.1250	0.4486
4	12.7606	0.3293	99.2578	0.7450	0.8040	**File Name**
5	12.4315	0.2985	94.1226	1.0448	0.9788	analy_orange_33
6	13.4701	0.3806	99.4920	0.4583	0.2580	

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 33

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 20



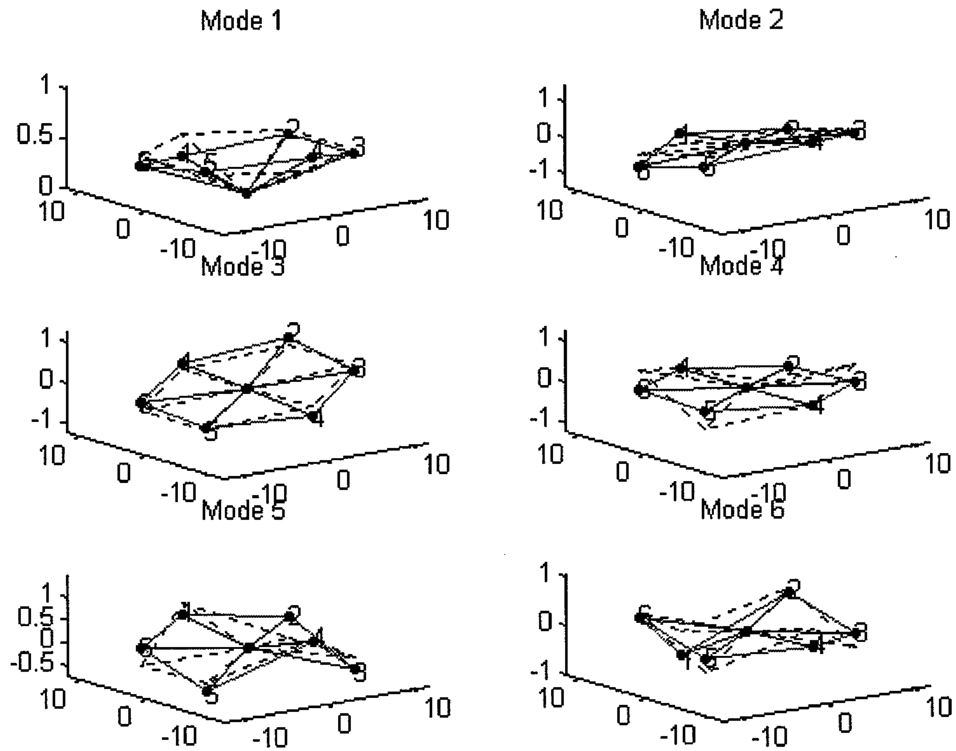
Mode 1	Mode2	Mode 3
0.0102 + 0.0124i	-0.0140 - 0.0178i	0.0063 - 0.0292i
0.0061 + 0.0081i	-0.0052 - 0.0065i	0.0133 - 0.0556i
0.0046 + 0.0073i	0.0037 + 0.0040i	0.0039 - 0.0157i
0.0235 + 0.0339i	0.0245 + 0.0331i	0.0010 - 0.0025i
0.0162 + 0.0223i	0.0009 + 0.0028i	-0.0038 + 0.0176i
0.0213 + 0.0260i	-0.0260 - 0.0309i	-0.0046 + 0.0213i
Mode 4	**Mode 5**	**Mode 6**
-0.0351 + 0.0499i	0.0162 + 0.0016i	-0.0102 - 0.0019i
0.0184 - 0.0275i	-0.0240 - 0.0031i	0.0308 + 0.0060i
0.0109 - 0.0160i	-0.0009 + 0.0001i	-0.0840 - 0.0172i
0.0012 - 0.0017i	0.0234 + 0.0030i	0.0150 + 0.0031i
-0.0144 + 0.0208i	-0.0643 - 0.0082i	-0.0057 - 0.0009i
0.0164 - 0.0238i	0.0168 + 0.0019i	0.0027 + 0.0004i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 34

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 20

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.7308	0.3445	98.5855	0.6278	0.5589	0.2891
2	11.0260	0.2190	97.5002	0.8804	0.6708	**Modal Density**
3	11.5573	0.3586	98.3766	0.6326	0.5759	0.6100
4	12.5349	0.2888	97.8627	0.6691	0.6819	**File Name**
5	12.2961	0.2608	96.8766	0.6836	0.4701	analy_orange_34
6	13.6158	0.4263	98.3536	0.4447	0.2302	



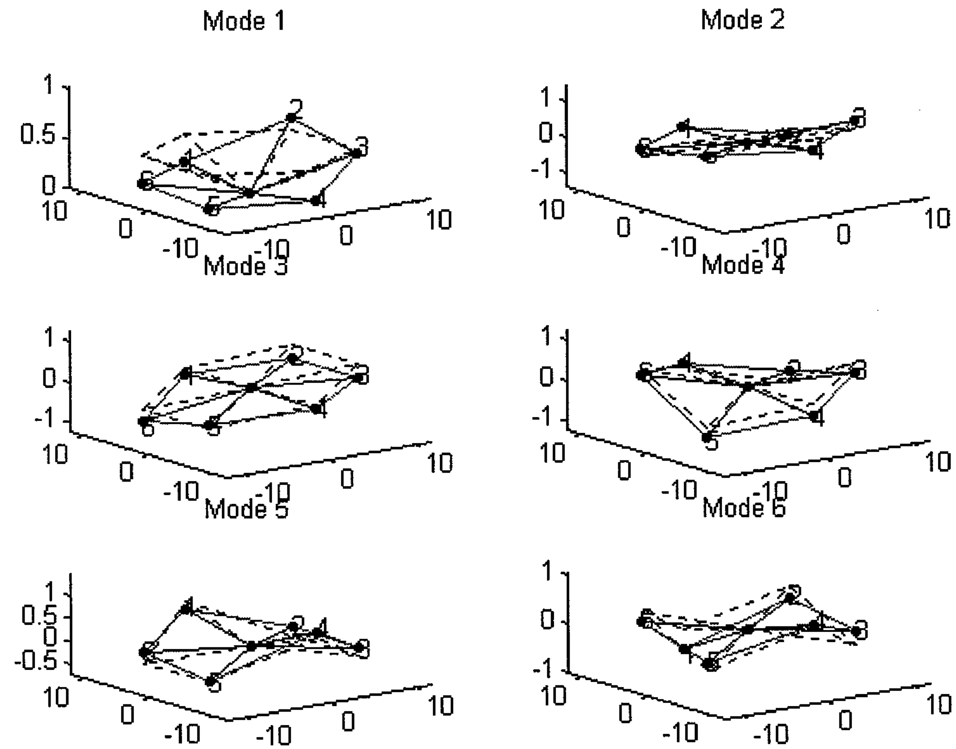
Mode 1	Mode2	Mode 3
0.0138 + 0.0040i	-0.0237 + 0.0102i	0.0100 + 0.0038i
0.0280 + 0.0090i	-0.0212 + 0.0063i	0.0507 + 0.0165i
0.0281 + 0.0086i	0.0137 - 0.0068i	0.0246 + 0.0073i
0.0423 + 0.0130i	0.0404 - 0.0146i	-0.0169 - 0.0061i
0.0351 + 0.0105i	-0.0046 + 0.0037i	-0.0354 - 0.0113i
0.0242 + 0.0074i	-0.0498 + 0.0196i	-0.0224 - 0.0065i
Mode 4	Mode 5	Mode 6
-0.0008 + 0.0023i	0.0281 + 0.0077i	-0.0854 - 0.0135i
-0.0034 - 0.0370i	0.0158 + 0.0044i	0.0294 + 0.0039i
0.0038 + 0.0383i	-0.0477 - 0.0136i	-0.0113 - 0.0010i
0.0007 + 0.0091i	0.0490 + 0.0134i	0.0062 + 0.0005i
-0.0036 - 0.0512i	-0.0417 - 0.0124i	-0.0113 - 0.0012i
0.0021 + 0.0409i	0.0068 + 0.0026i	0.0297 + 0.0040i

System Information
System: Orange Band (34.13 N/m)
PZT Coupling: Off
Mistuning: Set 35

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.2056	0.3086	99.2261	0.7064	0.7581	0.1721
2	11.7908	0.4804	98.3159	0.8449	0.7620	**Modal Density**
3	11.6008	0.3626	98.7946	0.7176	0.7922	0.4500
4	12.5309	0.2022	98.2922	0.8300	0.9512	**File Name**
5	12.7316	0.3400	99.2515	1.0229	0.9601	analy_orange_35
6	13.4932	0.4554	98.7428	0.4615	0.2645	



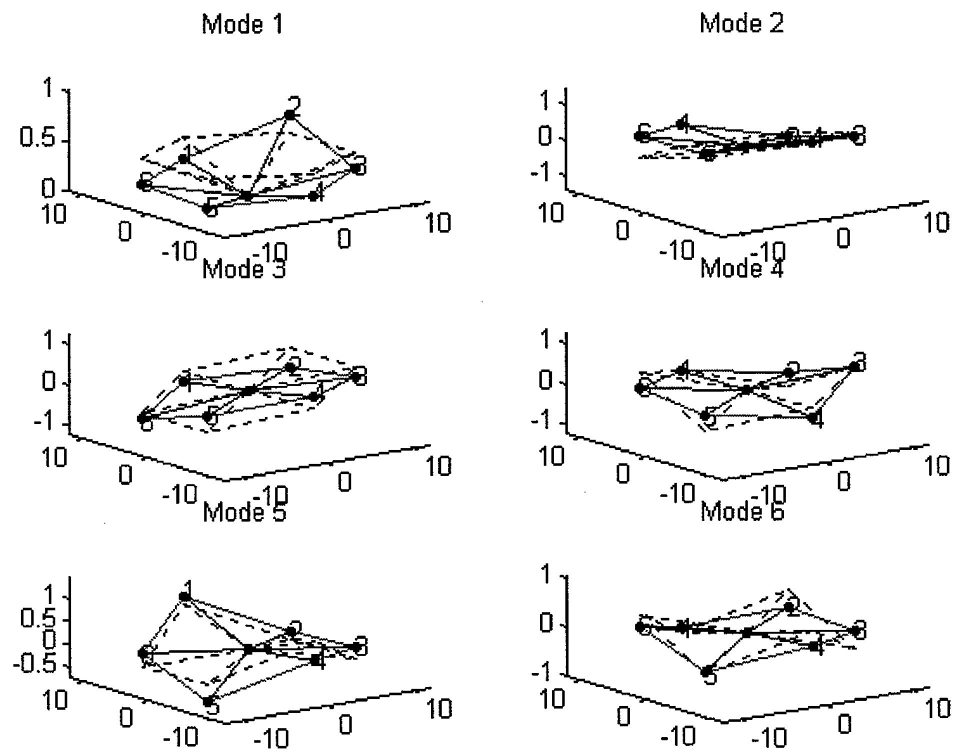
Mode 1	Mode2	Mode 3
0.0087 - 0.0087i	-0.0103 - 0.0095i	-0.0107 + 0.0037i
0.0342 - 0.0368i	-0.0305 - 0.0231i	0.0112 - 0.0048i
0.0242 - 0.0259i	0.0327 + 0.0247i	0.0104 - 0.0042i
0.0074 - 0.0065i	0.0184 + 0.0163i	-0.0046 + 0.0012i
0.0050 - 0.0056i	0.0153 + 0.0129i	-0.0261 + 0.0092i
0.0083 - 0.0098i	-0.0053 - 0.0048i	-0.0519 + 0.0216i
Mode 4	Mode 5	Mode 6
0.0067 - 0.0028i	0.0364 - 0.0137i	-0.0717 - 0.0019i
-0.0149 + 0.0066i	-0.0047 + 0.0007i	0.0158 + 0.0001i
0.0213 - 0.0096i	-0.0116 + 0.0082i	-0.0099 - 0.0021i
-0.0234 + 0.0098i	0.0688 - 0.0448i	0.0416 + 0.0122i
-0.0609 + 0.0264i	-0.0250 + 0.0181i	-0.0203 - 0.0042i
0.0283 - 0.0125i	-0.0034 - 0.0004i	0.0191 + 0.0007i

System Information
System: Orange Band (34.13N/m)
PZT Coupling: Off
Mistuning: Set 36

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.6350	0.2553	98.0052	0.5294	0.3751	0.3683
2	11.4937	0.2920	96.1176	0.9345	0.8735	**Modal Density**
3	11.0025	0.2287	98.6436	0.5866	0.4452	0.6013
4	12.0078	0.4148	98.1648	0.6243	0.5587	**File Name**
5	13.3038	0.4555	98.2355	0.6831	0.4575	analy_orange_36
6	13.4578	0.6649	66.8173	0.5144	0.3660	



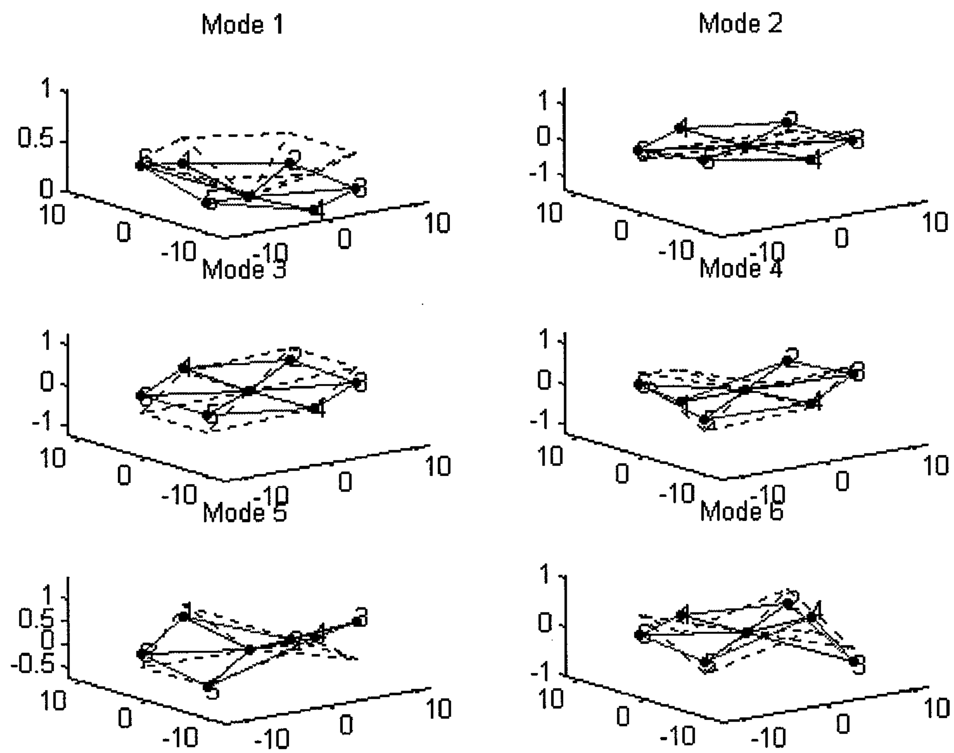
Mode 1	Mode2	Mode 3
0.0096 - 0.0090i	0.0010 - 0.0003i	-0.0173 + 0.0134i
0.0298 - 0.0286i	-0.0230 + 0.0097i	-0.0011 + 0.0010i
0.0123 - 0.0134i	0.0101 - 0.0043i	0.0158 - 0.0127i
0.0104 - 0.0108i	0.0397 - 0.0173i	0.0232 - 0.0189i
0.0052 - 0.0052i	0.0225 - 0.0096i	-0.0073 + 0.0053i
0.0075 - 0.0069i	0.0230 - 0.0097i	-0.0436 + 0.0340i
Mode 4	**Mode 5**	**Mode 6**
-0.0024 + 0.0030i	0.0382 - 0.0003i	-0.0122 + 0.0215i
-0.0123 + 0.0172i	-0.0050 + 0.0004i	0.0018 - 0.0030i
0.0458 - 0.0633i	-0.0011 + 0.0003i	-0.0015 + 0.0028i
-0.0207 + 0.0289i	0.0082 + 0.0000i	0.0034 - 0.0059i
-0.0112 + 0.0155i	-0.0335 - 0.0001i	-0.0151 + 0.0254i
0.0082 - 0.0111i	-0.0018 + 0.0000i	0.0062 - 0.0106i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 1

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.4708	0.5304	95.6408	0.5034	0.3601	0.0164
2	10.6791	0.2494	97.4543	0.8264	0.7908	**Modal Density**
3	11.1378	0.4218	93.2330	0.6347	0.5750	1.9260
4	13.3806	0.3454	98.4846	0.5861	0.4483	**File Name**
5	15.5799	0.2577	84.3222	0.7818	0.5279	analy_yellow_1
6	16.2003	0.1571	90.2949	0.5700	0.4170	



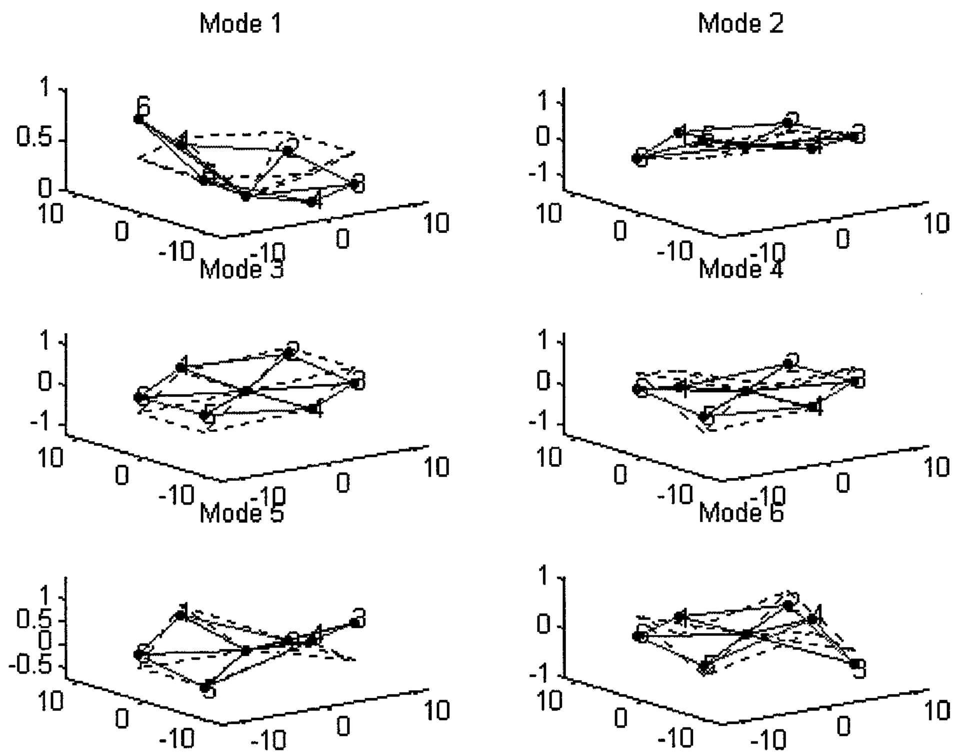
Mode 1	Mode2	Mode 3
0.0071 + 0.0145i	-0.0049 - 0.0165i	0.0037 + 0.0153i
0.0056 + 0.0104i	-0.0002 - 0.0009i	0.0130 + 0.0518i
0.0022 + 0.0039i	0.0042 + 0.0145i	0.0041 + 0.0159i
0.0029 + 0.0059i	0.0112 + 0.0391i	0.0005 + 0.0038i
0.0082 + 0.0170i	0.0174 + 0.0627i	-0.0022 - 0.0068i
0.0172 + 0.0358i	-0.0058 - 0.0206i	-0.0036 - 0.0137i
Mode 4	**Mode 5**	**Mode 6**
-0.0589 + 0.0301i	0.0210 + 0.0005i	-0.0017 - 0.0004i
0.0122 - 0.0062i	-0.0176 - 0.0001i	0.0053 + 0.0005i
0.0211 - 0.0111i	0.0345 + 0.0020i	-0.0255 - 0.0038i
0.0100 - 0.0048i	0.0424 + 0.0023i	0.0260 + 0.0038i
-0.0150 + 0.0081i	-0.0215 - 0.0013i	-0.0064 - 0.0007i
0.0147 - 0.0074i	-0.0001 + 0.0004i	0.0008 + 0.0003i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.5137	0.4827	96.2424	0.5036	0.3547	0.0967
2	12.0941	0.3289	95.2120	0.7353	0.5613	**Modal Density**
3	10.8442	0.3822	96.1179	0.5647	0.3980	2.1478
4	14.1903	0.3038	99.2609	0.5764	0.4297	**File Name**
5	14.6515	0.3644	91.2549	0.8828	0.8566	analy_yellow_2
6	16.8792	0.2635	84.7803	0.5883	0.3694	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 2

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



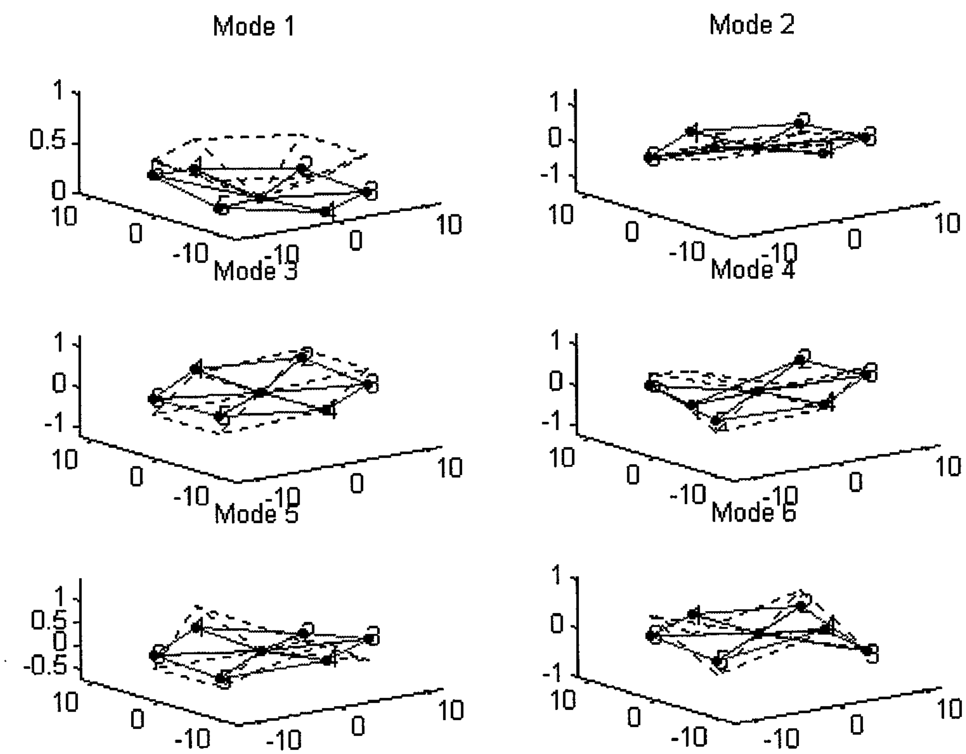
Mode 1	Mode2	Mode 3
0.0162 - 0.0005i	-0.0168 - 0.0039i	0.0059 + 0.0150i
0.0112 - 0.0010i	-0.0010 - 0.0001i	0.0197 + 0.0495i
0.0042 - 0.0003i	0.0146 + 0.0033i	0.0061 + 0.0154i
0.0072 - 0.0003i	0.0396 + 0.0093i	0.0016 + 0.0036i
0.0192 - 0.0008i	0.0630 + 0.0150i	-0.0026 - 0.0067i
0.0406 - 0.0019i	-0.0209 - 0.0050i	-0.0051 - 0.0127i
Mode 4	**Mode 5**	**Mode 6**
-0.0308 + 0.0576i	0.0210 + 0.0027i	-0.0024 + 0.0003i
0.0062 - 0.0120i	-0.0176 - 0.0022i	0.0052 - 0.0006i
0.0110 - 0.0214i	0.0339 + 0.0048i	-0.0254 + 0.0008i
0.0052 - 0.0098i	0.0412 + 0.0060i	0.0248 - 0.0010i
-0.0081 + 0.0153i	-0.0210 - 0.0031i	-0.0068 + 0.0002i
0.0078 - 0.0147i	-0.0001 + 0.0002i	0.0009 + 0.0001i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 2

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.5122	0.6120	97.1137	0.5000	0.3466	0.0985
2	12.0900	0.3310	97.2689	0.7373	0.5651	**Modal Density**
3	10.8556	0.4487	97.0367	0.5654	0.3996	2.1626
4	14.2087	0.2899	99.1841	0.5794	0.4376	**File Name**
5	14.6712	0.3565	86.6027	0.8901	0.8690	analy_yellow_2r1
6	16.9161	0.2994	81.5696	0.5889	0.3757	



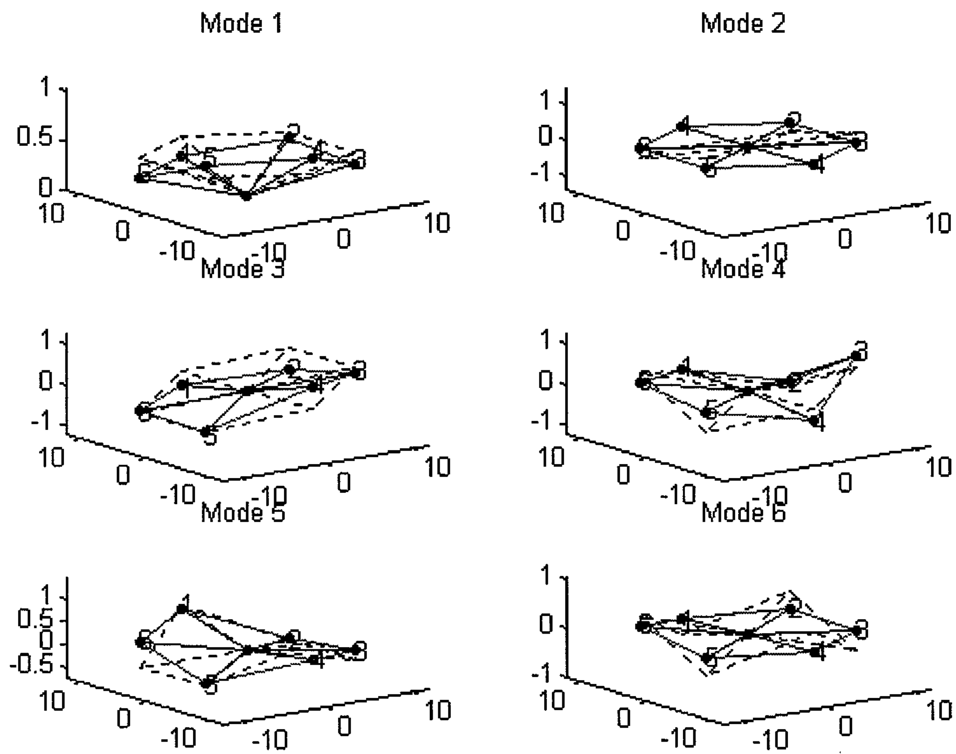
Mode 1	Mode2	Mode 3
0.0053 + 0.0148i	-0.0130 + 0.0106i	0.0050 + 0.0152i
0.0038 + 0.0110i	-0.0007 + 0.0004i	0.0167 + 0.0505i
0.0014 + 0.0040i	0.0117 - 0.0094i	0.0051 + 0.0156i
0.0028 + 0.0061i	0.0315 - 0.0252i	0.0010 + 0.0036i
0.0067 + 0.0174i	0.0509 - 0.0405i	-0.0024 - 0.0066i
0.0136 + 0.0374i	-0.0168 + 0.0132i	-0.0043 - 0.0127i
Mode 4	**Mode 5**	**Mode 6**
-0.0651 - 0.0187i	0.0064 - 0.0193i	-0.0012 - 0.0012i
0.0135 + 0.0037i	-0.0057 + 0.0170i	0.0039 + 0.0038i
0.0224 + 0.0062i	0.0120 - 0.0329i	-0.0175 - 0.0198i
0.0100 + 0.0031i	0.0147 - 0.0402i	0.0177 + 0.0192i
-0.0164 - 0.0042i	-0.0079 + 0.0207i	-0.0043 - 0.0046i
0.0159 + 0.0047i	0.0002 + 0.0001i	0.0008 + 0.0008i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.5046	0.3971	91.2281	0.4998	0.3467	0.1058
2	12.0953	0.3784	96.5290	0.7332	0.5570	**Modal Density**
3	10.8509	0.3554	98.6139	0.5640	0.3963	2.1416
4	14.1685	0.3130	99.2131	0.5716	0.4170	**File Name**
5	14.6265	0.3454	97.2987	0.8838	0.8544	analy_yellow_2r2
6	16.8464	0.2933	89.0546	0.5891	0.3684	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 2

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40



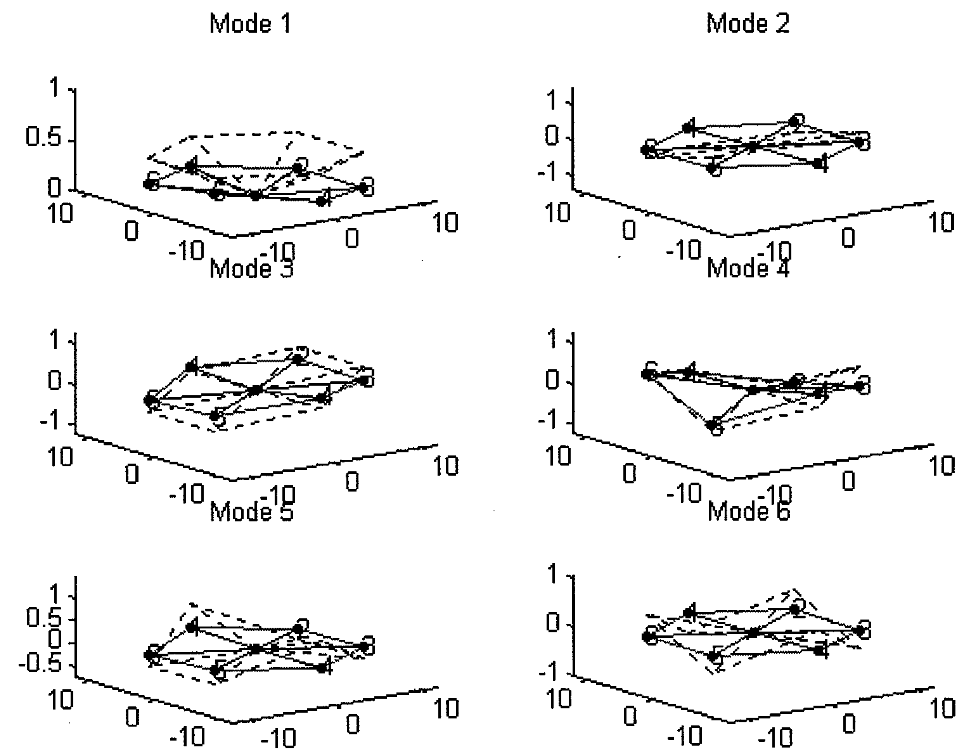
Mode 1	Mode2	Mode 3
0.0109 + 0.0035i	-0.0002 + 0.0211i	-0.0271 - 0.0028i
0.0186 + 0.0063i	0.0002 + 0.0481i	-0.0022 - 0.0005i
0.0152 + 0.0057i	0.0007 + 0.0126i	0.0243 + 0.0028i
0.0308 + 0.0100i	-0.0002 - 0.0174i	0.0387 + 0.0046i
0.0283 + 0.0088i	-0.0002 - 0.0252i	-0.0368 - 0.0044i
0.0117 + 0.0038i	-0.0002 - 0.0016i	-0.0316 - 0.0035i
Mode 4	**Mode 5**	**Mode 6**
0.0047 + 0.0020i	0.0356 + 0.0410i	-0.0071 - 0.0284i
-0.0294 - 0.0123i	-0.0161 - 0.0178i	0.0020 + 0.0074i
0.0712 + 0.0310i	-0.0059 - 0.0070i	-0.0010 - 0.0061i
-0.0266 - 0.0113i	0.0144 + 0.0166i	0.0011 + 0.0044i
0.0018 + 0.0006i	-0.0186 - 0.0214i	-0.0032 - 0.0129i
0.0241 + 0.0105i	0.0174 + 0.0197i	0.0131 + 0.0524i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 3

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 45

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.3175	0.2916	96.1005	0.6746	0.6410	0.0304
2	10.1100	0.2616	97.4149	0.7455	0.6127	**Modal Density**
3	11.1210	0.3288	97.6289	0.9302	1.1253	1.4595
4	13.3911	0.3486	97.5375	0.5973	0.4799	**File Name**
5	12.4364	0.2705	98.9449	0.7943	0.7500	analy_yellow_3
6	14.6124	0.3427	97.8335	0.4819	0.2970	



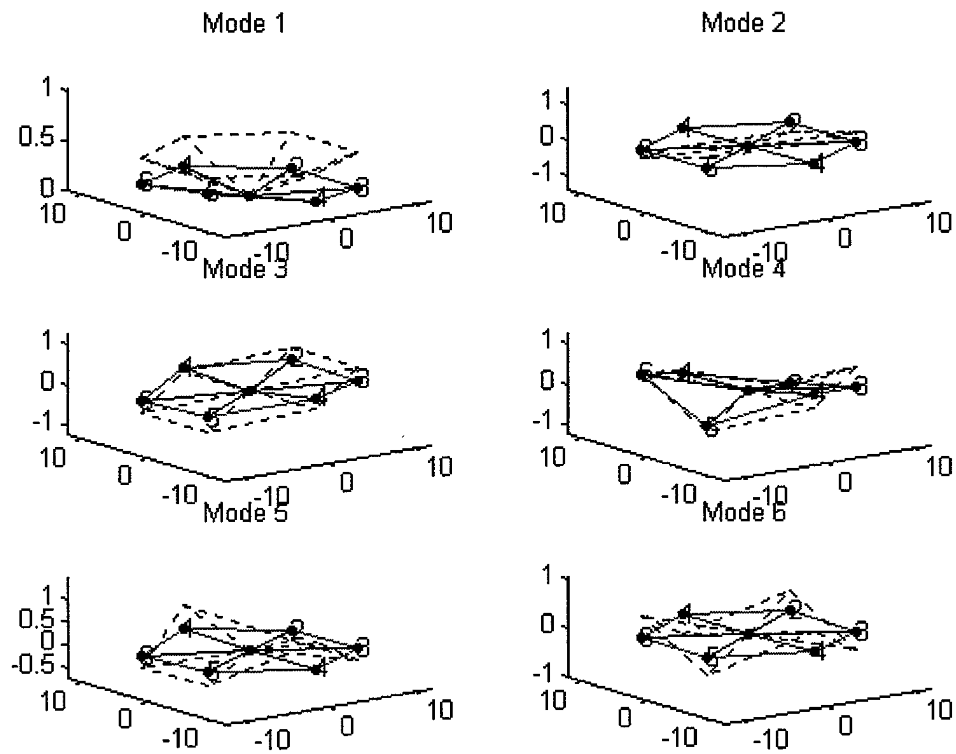
Mode 1	Mode2	Mode 3
0.0177 + 0.0386i	-0.0344 - 0.0139i	-0.0112 + 0.0074i
0.0120 + 0.0256i	-0.0236 - 0.0099i	0.0566 - 0.0383i
0.0048 + 0.0104i	0.0063 + 0.0024i	0.0302 - 0.0205i
0.0089 + 0.0182i	0.0472 + 0.0191i	0.0379 - 0.0247i
0.0112 + 0.0239i	0.0469 + 0.0193i	-0.0154 + 0.0110i
0.0140 + 0.0293i	0.0082 + 0.0037i	-0.0481 + 0.0324i
Mode 4	**Mode 5**	**Mode 6**
-0.0082 - 0.0067i	0.0037 - 0.0328i	-0.0006 - 0.0017i
0.0001 - 0.0001i	-0.0047 + 0.0404i	0.0009 + 0.0075i
0.0075 + 0.0056i	-0.0002 + 0.0033i	-0.0051 - 0.0286i
0.0124 + 0.0103i	0.0041 - 0.0331i	0.0012 + 0.0060i
-0.0254 - 0.0203i	-0.0019 + 0.0197i	-0.0005 - 0.0016i
0.0237 + 0.0197i	-0.0034 + 0.0231i	-0.0002 + 0.0005i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 4

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9697	0.3733	98.6424	0.6727	0.7039	0.0818
2	12.0578	0.3478	98.2350	0.9697	0.8560	**Modal Density**
3	13.0130	0.3899	99.6157	0.7997	0.9098	1.8585
4	15.3337	0.3147	94.4930	0.7634	0.7206	**File Name**
5	14.3893	0.3691	97.4298	0.9841	1.0284	analy_yellow_4
6	18.5466	0.3949	73.5807	0.4320	0.2077	



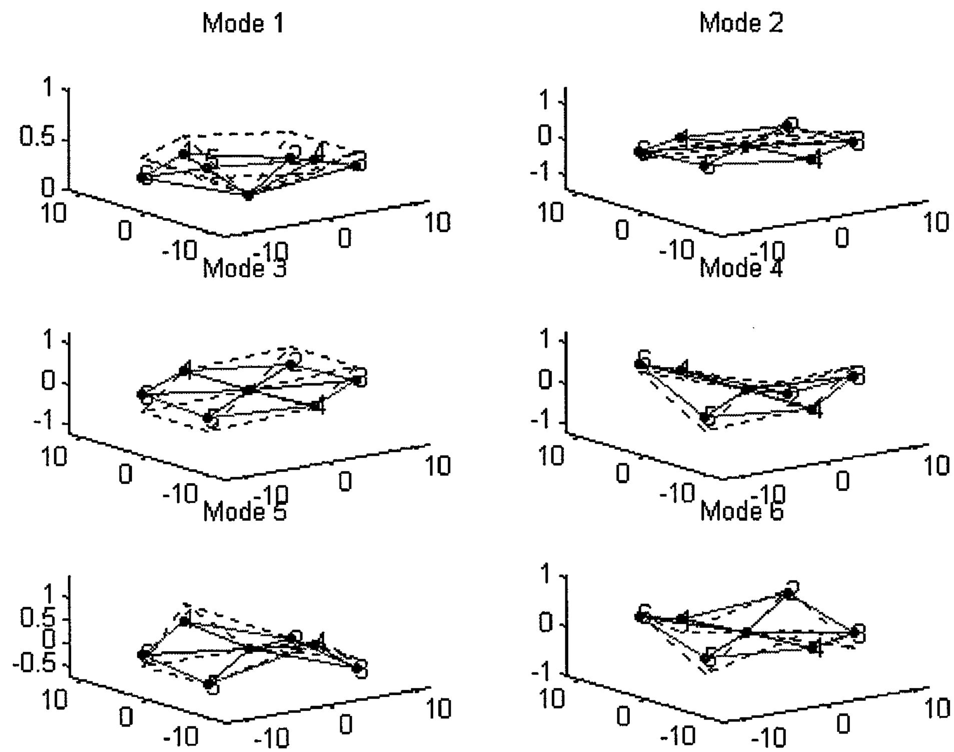
Mode 1	Mode2	Mode 3
0.0067 - 0.0177i	-0.0039 + 0.0567i	0.0080 + 0.0166i
0.0037 - 0.0099i	-0.0018 + 0.0305i	0.0221 + 0.0465i
0.0032 - 0.0088i	0.0001 + 0.0001i	0.0172 + 0.0360i
0.0100 - 0.0281i	0.0023 - 0.0293i	0.0268 + 0.0586i
0.0164 - 0.0441i	0.0014 - 0.0255i	-0.0131 - 0.0280i
0.0104 - 0.0287i	-0.0023 + 0.0307i	-0.0181 - 0.0394i
Mode 4	**Mode 5**	**Mode 6**
-0.0040 + 0.0036i	0.0028 + 0.0283i	-0.0005 - 0.0030i
-0.0227 + 0.0186i	-0.0022 - 0.0298i	0.0002 + 0.0119i
-0.0012 + 0.0009i	-0.0016 - 0.0153i	-0.0010 - 0.0274i
0.0206 - 0.0164i	0.0007 + 0.0072i	0.0003 + 0.0065i
-0.0203 + 0.0168i	0.0006 + 0.0040i	-0.0007 - 0.0013i
0.0248 - 0.0196i	-0.0018 - 0.0191i	-0.0007 + 0.0009i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.9478	0.3933	98.8787	0.5880	0.5243	0.2309
2	12.4174	0.4342	85.6112	0.8273	0.8216	**Modal Density**
3	13.3658	0.3670	99.3886	0.8345	1.0668	1.9496
4	14.8461	0.3094	96.3875	0.9060	0.9946	**File Name**
5	15.6193	0.2888	95.9825	0.9419	0.8570	analy_yellow_5
6	18.8022	0.3841	80.2213	0.4587	0.2556	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 5

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40



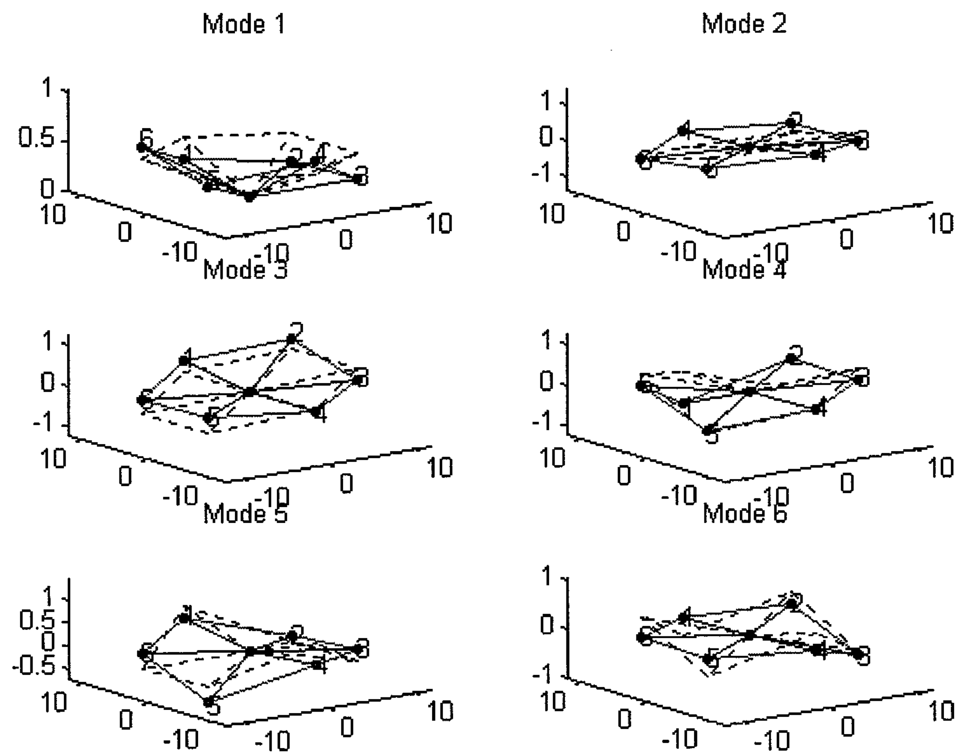
Mode 1	Mode2	Mode 3
0.0116 - 0.0066i	-0.0223 + 0.0512i	0.0001 - 0.0012i
0.0082 - 0.0045i	-0.0081 + 0.0187i	0.0057 + 0.0214i
0.0145 - 0.0082i	-0.0003 - 0.0003i	0.0116 + 0.0438i
0.0288 - 0.0166i	0.0076 - 0.0189i	0.0053 + 0.0218i
0.0266 - 0.0153i	0.0033 - 0.0083i	-0.0128 - 0.0493i
0.0108 - 0.0061i	-0.0065 + 0.0150i	-0.0052 - 0.0203i
Mode 4	**Mode 5**	**Mode 6**
-0.0001 - 0.0002i	0.0177 - 0.0133i	-0.0059 - 0.0088i
-0.0351 - 0.0003i	-0.0240 + 0.0176i	0.0124 + 0.0221i
0.0113 - 0.0005i	-0.0444 + 0.0329i	-0.0039 - 0.0066i
-0.0005 - 0.0005i	0.0455 - 0.0333i	0.0016 + 0.0020i
-0.0073 + 0.0003i	-0.0275 + 0.0207i	-0.0035 - 0.0054i
0.0351 - 0.0001i	-0.0061 + 0.0046i	0.0148 + 0.0235i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 6

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9539	0.5528	97.4721	0.6429	0.5583	0.5392
2	11.0142	0.3152	96.9725	0.6775	0.4545	**Modal Density**
3	11.6937	0.3471	95.7081	0.7661	0.7960	1.6053
4	15.5872	0.2780	92.0581	0.7328	0.5733	**File Name**
5	13.1214	0.3156	99.3743	0.9631	0.8952	analy_yellow_6
6	16.0666	0.2926	95.0815	0.5942	0.4336	



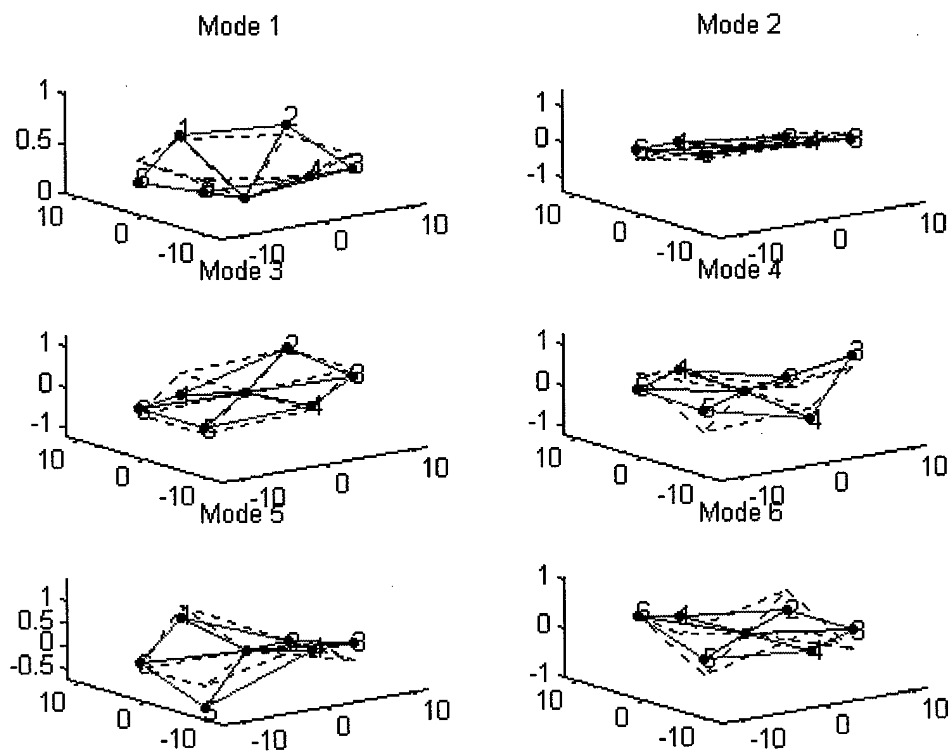
Mode 1	Mode2	Mode 3
0.0101 + 0.0052i	-0.0065 + 0.0128i	0.0268 - 0.0168i
0.0067 + 0.0038i	-0.0010 + 0.0012i	0.0668 - 0.0419i
0.0077 + 0.0041i	0.0038 - 0.0079i	0.0178 - 0.0115i
0.0294 + 0.0158i	0.0181 - 0.0365i	-0.0050 + 0.0031i
0.0177 + 0.0094i	0.0001 - 0.0005i	-0.0090 + 0.0055i
0.0282 + 0.0144i	-0.0178 + 0.0368i	-0.0106 + 0.0067i
Mode 4	**Mode 5**	**Mode 6**
-0.0330 - 0.0066i	0.0151 + 0.0146i	-0.0016 + 0.0033i
0.0103 + 0.0026i	-0.0065 - 0.0070i	0.0051 - 0.0067i
0.0090 + 0.0019i	-0.0009 - 0.0006i	-0.0155 + 0.0275i
0.0017 + 0.0005i	0.0054 + 0.0061i	0.0014 - 0.0031i
-0.0191 - 0.0025i	-0.0298 - 0.0316i	-0.0008 + 0.0016i
0.0088 + 0.0016i	0.0021 + 0.0031i	-0.0001 - 0.0001i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9628	0.5405	97.3541	0.6451	0.5309	0.2074
2	10.5988	0.2939	87.4268	0.8493	0.5849	**Modal Density**
3	12.6237	0.4554	98.4388	0.5661	0.3981	2.4116
4	16.0436	0.2843	94.5213	0.6279	0.5510	**File Name**
5	15.6650	0.2846	89.0880	0.6651	0.4158	analy_yellow_7
6	18.4017	0.3740	72.1671	0.4280	0.2004	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 7

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



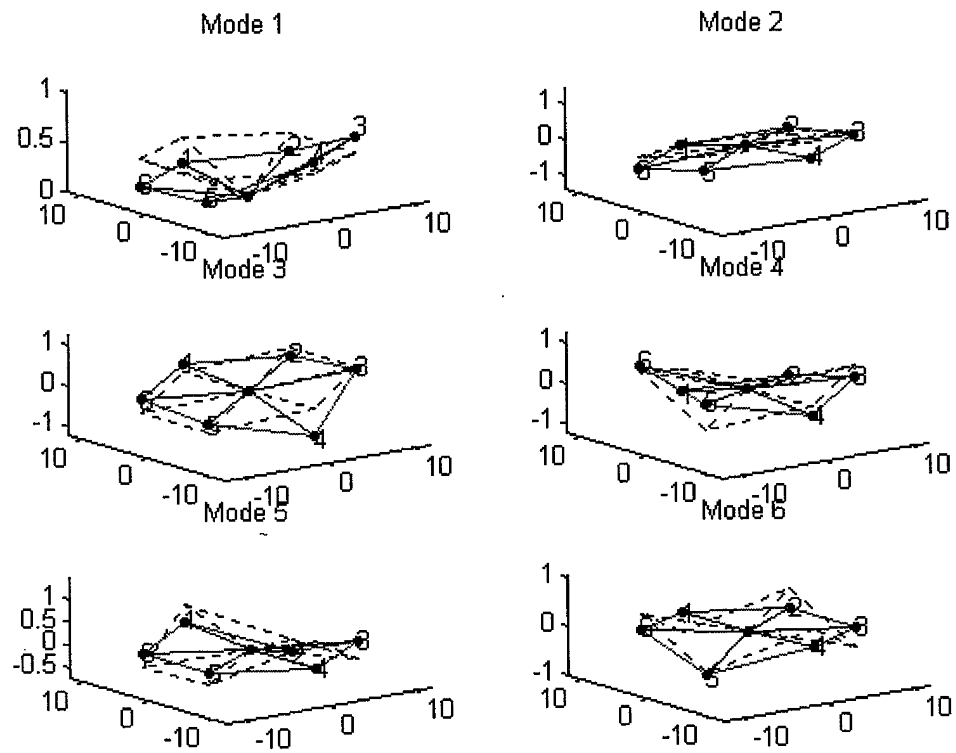
Mode 1	Mode2	Mode 3
0.0288 + 0.0134i	-0.0270 - 0.0114i	-0.0536 - 0.0202i
0.0339 + 0.0155i	-0.0255 - 0.0109i	0.0525 + 0.0191i
0.0172 + 0.0081i	0.0054 + 0.0025i	0.0302 + 0.0109i
0.0272 + 0.0129i	0.0416 + 0.0191i	0.0097 + 0.0034i
0.0187 + 0.0091i	0.0263 + 0.0121i	-0.0346 - 0.0125i
0.0132 + 0.0061i	-0.0007 - 0.0001i	-0.0334 - 0.0121i
Mode 4	**Mode 5**	**Mode 6**
0.0015 - 0.0008i	0.0243 + 0.0079i	-0.0021 + 0.0051i
-0.0099 + 0.0057i	-0.0223 - 0.0073i	0.0001 - 0.0010i
0.0316 - 0.0192i	0.0085 + 0.0029i	-0.0008 + 0.0012i
-0.0095 + 0.0062i	0.0322 + 0.0106i	0.0008 - 0.0016i
0.0027 - 0.0015i	-0.0573 - 0.0194i	-0.0030 + 0.0075i
0.0047 - 0.0034i	-0.0145 - 0.0050i	0.0138 - 0.0297i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 8

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.7230	0.4101	98.5009	0.7193	0.7499	0.0158
2	11.4720	0.3323	94.6951	0.8547	0.8219	**Modal Density**
3	12.8146	0.3345	99.6020	0.8796	1.0311	1.9194
4	16.2612	0.2514	93.8596	0.5528	0.3667	**File Name**
5	14.0684	0.2949	98.9273	0.7591	0.6456	analy_yellow_8
6	18.3217	0.2704	83.1339	0.4272	0.1990	



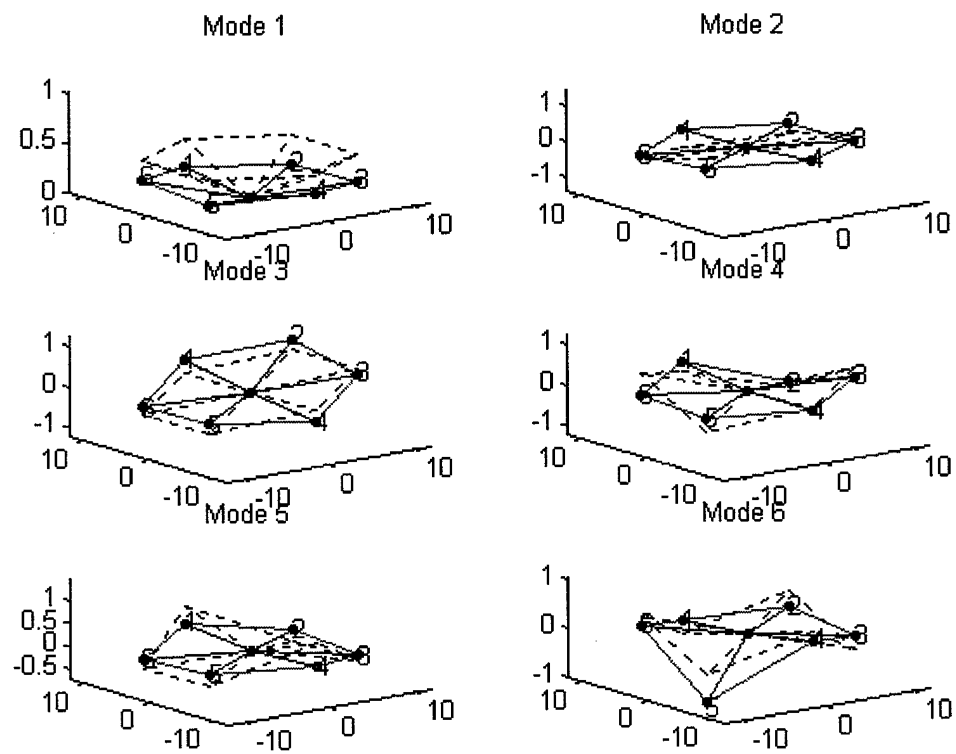
Mode 1	Mode2	Mode 3
0.0075 + 0.0047i	-0.0426 - 0.0208i	0.0124 - 0.0043i
0.0117 + 0.0069i	-0.0103 - 0.0051i	0.0219 - 0.0085i
0.0275 + 0.0162i	0.0128 + 0.0055i	0.0320 - 0.0127i
0.0258 + 0.0145i	0.0099 + 0.0048i	-0.0509 + 0.0196i
0.0086 + 0.0051i	-0.0094 - 0.0045i	-0.0209 + 0.0081i
0.0066 + 0.0043i	-0.0432 - 0.0207i	-0.0123 + 0.0048i
Mode 4	**Mode 5**	**Mode 6**
-0.0552 - 0.0224i	0.0082 - 0.0108i	-0.0011 + 0.0011i
-0.0261 - 0.0106i	-0.0241 + 0.0356i	0.0001 - 0.0010i
0.0173 + 0.0064i	0.0038 - 0.0055i	-0.0004 + 0.0007i
-0.0207 - 0.0081i	-0.0001 + 0.0004i	0.0019 - 0.0044i
0.0159 + 0.0065i	-0.0018 + 0.0031i	-0.0149 + 0.0297i
0.0620 + 0.0253i	-0.0013 + 0.0033i	0.0032 - 0.0044i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 9

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9058	0.5401	98.2634	0.6154	0.4812	0.0496
2	11.1184	0.5794	97.1399	0.8606	0.6247	**Modal Density**
3	11.7906	0.2594	99.1756	0.6833	0.7098	2.3290
4	13.1582	0.3420	98.9621	0.7454	0.7336	**File Name**
5	15.7738	0.2050	83.7171	0.6157	0.3201	analy_yellow_9
6	18.0736	0.1842	67.9424	0.4187	0.1842	



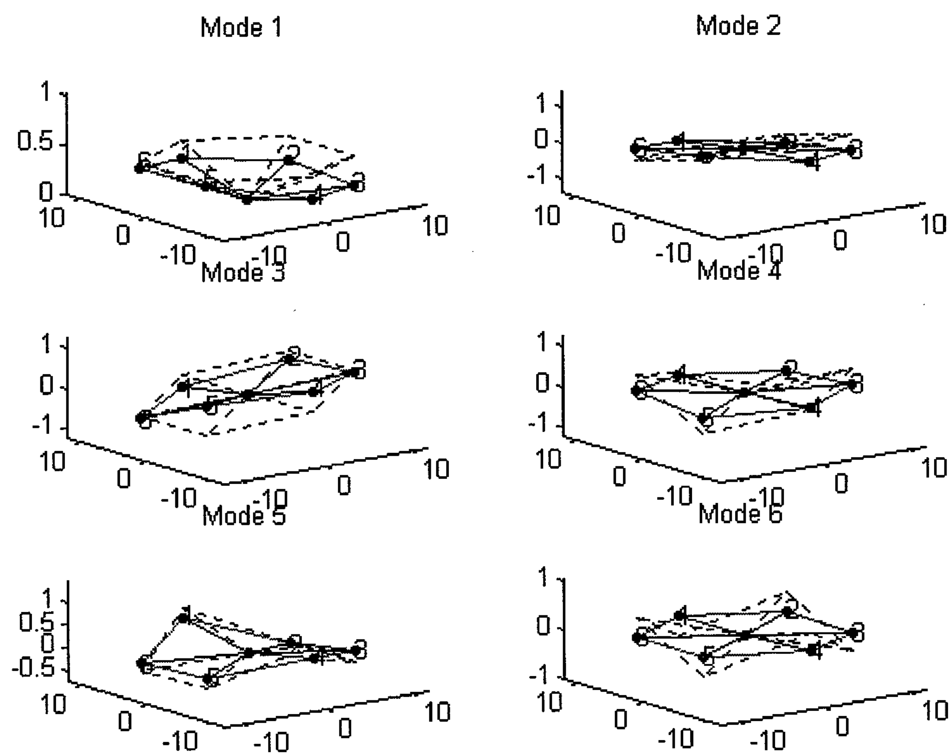
Mode 1	Mode2	Mode 3
0.0064 - 0.0151i	-0.0046 - 0.0192i	0.0198 - 0.0054i
0.0055 - 0.0142i	0.0001 - 0.0022i	0.0475 - 0.0131i
0.0060 - 0.0137i	0.0036 + 0.0131i	0.0207 - 0.0056i
0.0117 - 0.0241i	0.0070 + 0.0302i	-0.0168 + 0.0045i
0.0070 - 0.0153i	0.0002 + 0.0005i	-0.0165 + 0.0040i
0.0107 - 0.0228i	-0.0074 - 0.0301i	-0.0200 + 0.0052i
Mode 4	**Mode 5**	**Mode 6**
0.0221 + 0.0399i	0.0134 - 0.0484i	-0.0083 - 0.0003i
-0.0305 - 0.0552i	-0.0007 + 0.0020i	0.0060 - 0.0001i
0.0239 + 0.0428i	-0.0110 + 0.0409i	-0.0081 + 0.0001i
-0.0034 - 0.0058i	0.0051 - 0.0190i	0.0154 - 0.0001i
-0.0137 - 0.0253i	-0.0005 + 0.0015i	-0.0693 - 0.0004i
-0.0030 - 0.0053i	-0.0061 + 0.0223i	0.0155 + 0.0001i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 10

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.0444	0.5088	97.4945	0.7401	0.7911	0.1726
2	9.7340	0.2142	92.3733	0.9314	0.7699	**Modal Density**
3	10.5370	0.2683	98.9372	0.6672	0.7038	1.4773
4	13.0615	0.2733	98.8523	0.7672	0.8246	**File Name**
5	12.2121	0.3362	94.1606	0.8331	0.6874	analy_yellow_10
6	14.2353	0.3123	97.2506	0.4350	0.2137	



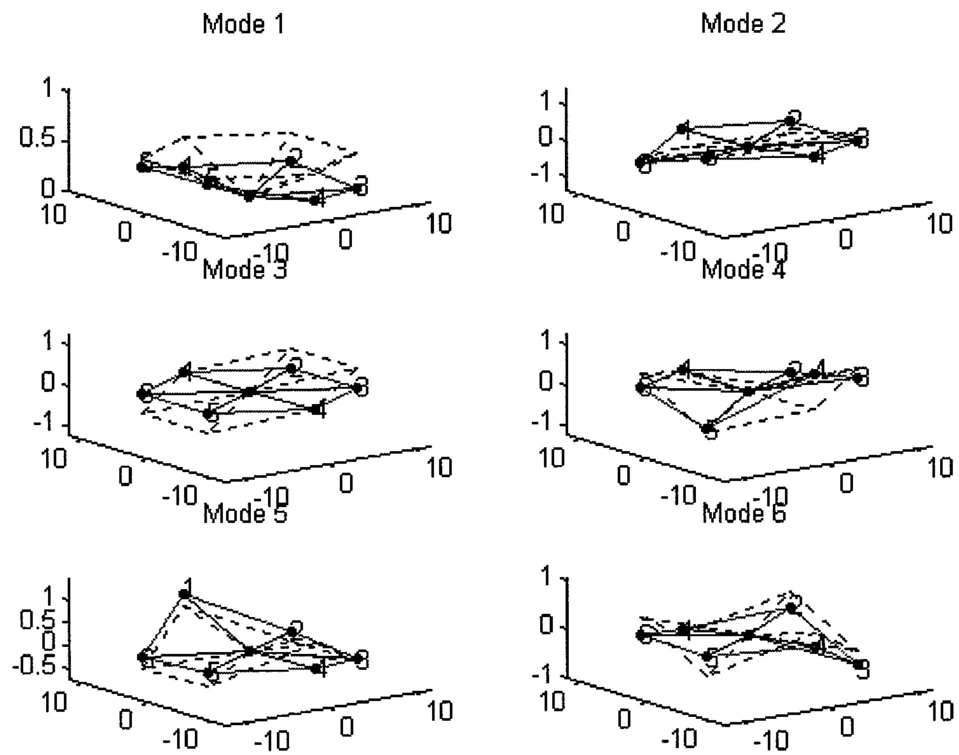
Mode 1	Mode2	Mode 3
0.0132 - 0.0161i	-0.0214 + 0.0195i	-0.0180 + 0.0063i
0.0103 - 0.0122i	-0.0309 + 0.0291i	0.0176 - 0.0047i
0.0065 - 0.0085i	-0.0108 + 0.0099i	0.0258 - 0.0083i
0.0115 - 0.0142i	0.0079 - 0.0072i	0.0315 - 0.0104i
0.0207 - 0.0250i	0.0241 - 0.0220i	0.0138 - 0.0044i
0.0201 - 0.0247i	0.0034 - 0.0034i	-0.0319 + 0.0100i
Mode 4	Mode 5	Mode 6
-0.0046 + 0.0233i	0.0300 + 0.0464i	-0.0006 + 0.0134i
-0.0030 + 0.0176i	-0.0231 - 0.0364i	0.0017 - 0.0270i
0.0066 - 0.0342i	-0.0017 - 0.0019i	-0.0035 + 0.0498i
0.0054 - 0.0263i	0.0237 + 0.0371i	0.0033 - 0.0443i
-0.0071 + 0.0367i	-0.0061 - 0.0100i	-0.0010 + 0.0153i
0.0070 - 0.0357i	-0.0121 - 0.0183i	0.0005 - 0.0078i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 11

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.3029	0.4631	98.6094	0.7112	0.6801	0.2279
2	10.4017	0.3916	98.5206	0.8664	0.8003	**Modal Density**
3	10.7981	0.4422	98.7909	0.9288	1.1327	1.2653
4	12.4251	0.2684	99.3005	0.9957	1.2540	**File Name**
5	12.7279	0.2749	99.0242	0.9031	0.8324	analy_yellow_11
6	14.0016	0.2536	98.4834	0.6157	0.4999	



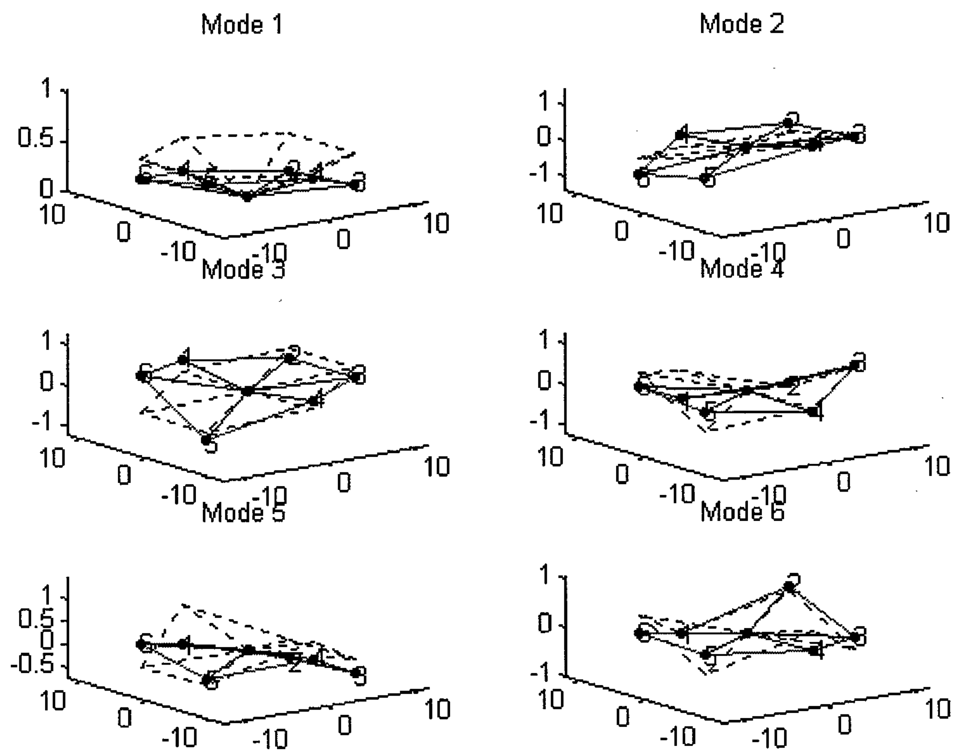
Mode 1	Mode2	Mode 3
0.0047 + 0.0066i	-0.0056 - 0.0088i	-0.0003 - 0.0096i
0.0060 + 0.0075i	0.0027 + 0.0030i	-0.0007 - 0.0462i
0.0027 + 0.0035i	0.0042 + 0.0059i	0.0002 - 0.0096i
0.0071 + 0.0116i	0.0151 + 0.0232i	-0.0004 + 0.0022i
0.0165 + 0.0269i	0.0171 + 0.0256i	0.0001 + 0.0130i
0.0154 + 0.0245i	-0.0244 - 0.0360i	-0.0004 + 0.0046i
Mode 4	**Mode 5**	**Mode 6**
0.0010 + 0.0003i	0.0294 - 0.0190i	-0.0093 + 0.0073i
-0.0071 - 0.0001i	-0.0017 + 0.0008i	0.0035 - 0.0020i
0.0166 + 0.0008i	-0.0084 + 0.0041i	-0.0236 + 0.0207i
0.0652 + 0.0033i	0.0012 - 0.0012i	0.0049 - 0.0026i
-0.0284 - 0.0009i	0.0001 - 0.0004i	-0.0007 + 0.0007i
0.0095 + 0.0005i	-0.0027 + 0.0014i	0.0011 - 0.0003i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 12

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 24

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.0096	0.2012	97.4275	0.6067	0.4619	0.0528
2	10.6665	0.3267	95.4092	0.8167	0.7044	**Modal Density**
3	9.8092	0.3505	87.8563	0.5428	0.3438	3.1246
4	12.5307	0.3803	96.4574	0.5674	0.3985	**File Name**
5	17.8055	0.2539	75.3696	0.6012	0.2924	analy_yellow_12
6	18.2977	0.4548	74.4123	0.4457	0.2318	



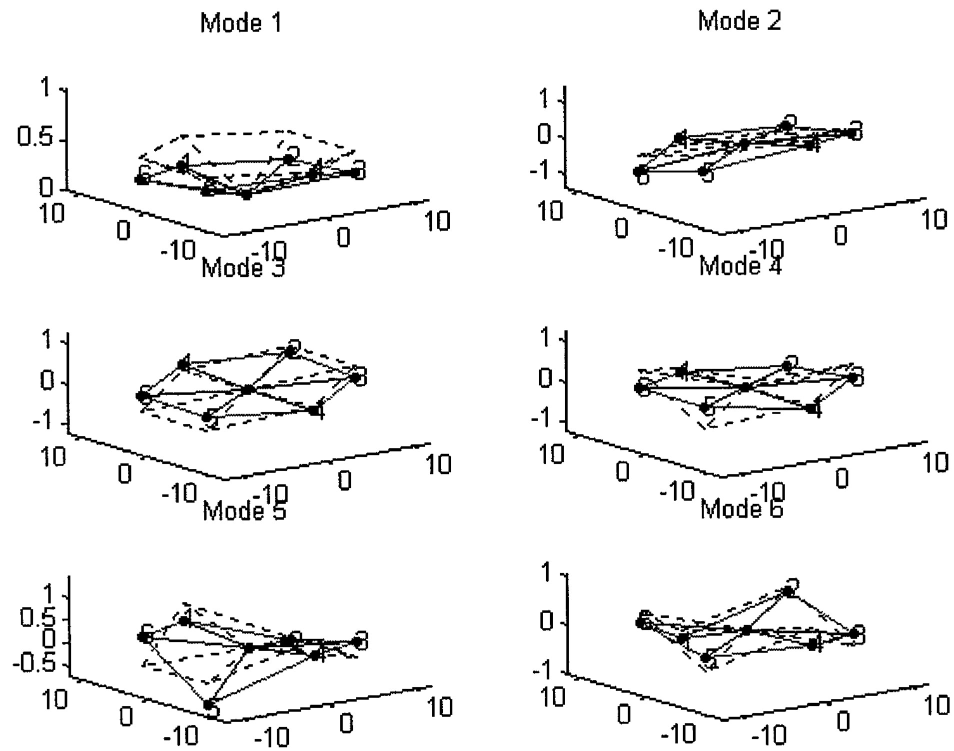
Mode 1	Mode2	Mode 3
0.0029 - 0.0045i	-0.0128 - 0.0002i	0.0199 - 0.0078i
0.0017 - 0.0030i	-0.0004 - 0.0002i	0.0178 - 0.0070i
0.0044 - 0.0070i	0.0098 - 0.0005i	0.0187 - 0.0073i
0.0177 - 0.0253i	0.0306 - 0.0002i	0.0171 - 0.0070i
0.0162 - 0.0230i	-0.0145 - 0.0002i	-0.0498 + 0.0201i
0.0101 - 0.0145i	-0.0417 - 0.0003i	0.0320 - 0.0125i
Mode 4	**Mode 5**	**Mode 6**
-0.0419 - 0.0091i	-0.0287 + 0.0065i	-0.0153 + 0.0180i
-0.0246 - 0.0059i	-0.0694 + 0.0167i	0.0175 - 0.0214i
0.0313 + 0.0059i	-0.0616 + 0.0145i	-0.0060 + 0.0077i
-0.0053 - 0.0011i	0.0232 - 0.0061i	0.0004 - 0.0006i
-0.0005 - 0.0004i	-0.0175 + 0.0046i	-0.0008 + 0.0004i
0.0091 + 0.0018i	0.0187 - 0.0049i	0.0015 - 0.0022i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 13

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.0624	0.4464	91.8338	0.6155	0.4776	0.1256
2	10.3080	0.3707	88.8843	0.7762	0.6212	**Modal Density**
3	11.7616	0.2257	98.9308	0.6988	0.7675	2.4407
4	14.8001	0.2920	94.4789	0.7006	0.6747	**File Name**
5	13.0480	0.4161	99.1143	0.8578	0.7295	analy_yellow_13
6	16.8101	0.1787	80.7870	0.5579	0.3746	



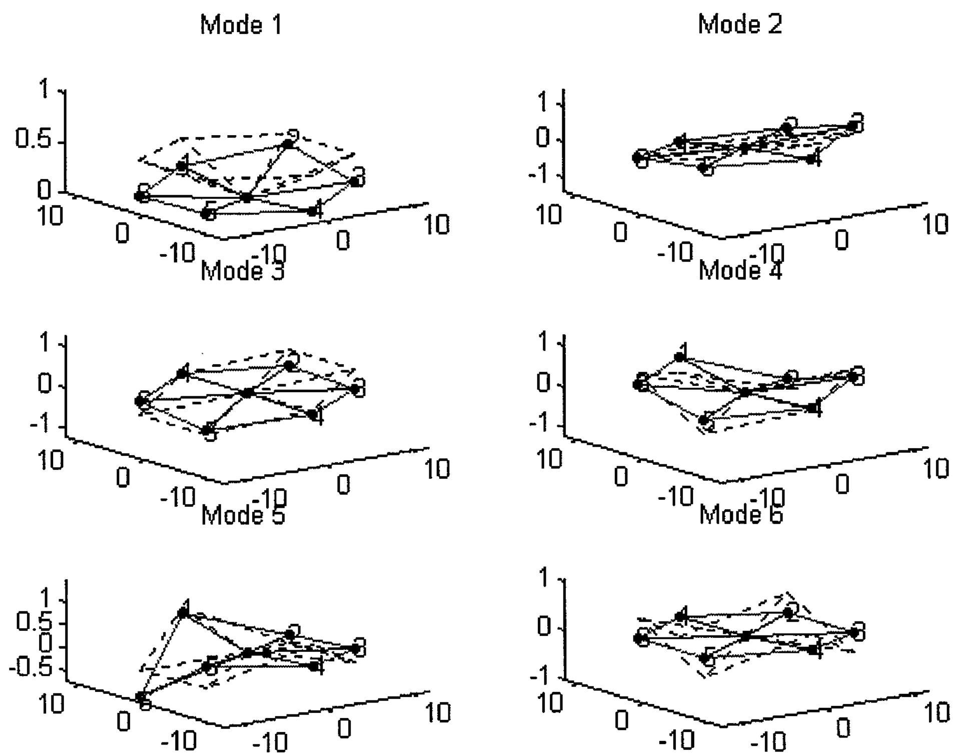
Mode 1	Mode2	Mode 3
0.0059 - 0.0084i	-0.0242 + 0.0013i	0.0081 - 0.0174i
0.0073 - 0.0102i	-0.0082 - 0.0004i	0.0246 - 0.0500i
0.0101 - 0.0138i	0.0106 - 0.0014i	0.0135 - 0.0273i
0.0212 - 0.0300i	0.0267 - 0.0016i	-0.0049 + 0.0113i
0.0143 - 0.0200i	-0.0107 + 0.0017i	-0.0117 + 0.0233i
0.0107 - 0.0147i	-0.0434 + 0.0031i	-0.0068 + 0.0119i
Mode 4	**Mode 5**	**Mode 6**
-0.0085 - 0.0427i	0.0174 + 0.0071i	-0.0311 - 0.0311i
-0.0052 - 0.0298i	-0.0279 - 0.0132i	0.0173 + 0.0175i
0.0126 + 0.0653i	0.0063 + 0.0048i	-0.0092 - 0.0092i
-0.0055 - 0.0272i	0.0225 + 0.0098i	0.0039 + 0.0039i
0.0034 + 0.0109i	-0.0678 - 0.0314i	-0.0080 - 0.0074i
0.0032 + 0.0191i	0.0296 + 0.0143i	0.0124 + 0.0127i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.6398	0.3060	97.1501	0.5923	0.5560	0.2018
2	10.8341	0.3895	97.4120	0.7841	0.6824	**Modal Density**
3	11.2993	0.4397	99.3243	0.6603	0.6573	1.3586
4	13.4883	0.2910	98.5953	0.6935	0.7315	**File Name**
5	13.3198	0.2794	98.5785	0.7181	0.5527	analy_yellow_14
6	14.8044	0.3280	96.6096	0.5225	0.3941	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 14

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40



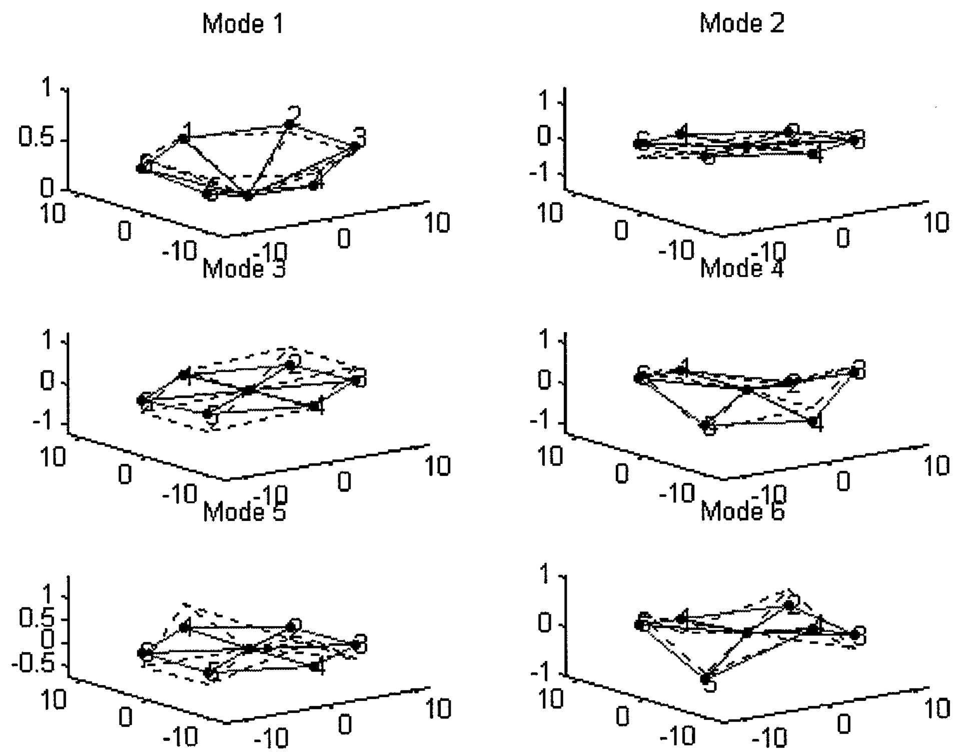
Mode 1	Mode2	Mode 3
0.0067 - 0.0169i	-0.0309 - 0.0282i	-0.0007 + 0.0021i
0.0166 - 0.0401i	-0.0072 - 0.0069i	0.0065 - 0.0144i
0.0075 - 0.0182i	0.0369 + 0.0345i	0.0007 - 0.0016i
0.0033 - 0.0072i	0.0136 + 0.0127i	-0.0057 + 0.0120i
0.0042 - 0.0099i	0.0033 + 0.0025i	-0.0217 + 0.0463i
0.0033 - 0.0081i	-0.0171 - 0.0155i	-0.0081 + 0.0179i
Mode 4	**Mode 5**	**Mode 6**
0.0300 + 0.0391i	0.0288 - 0.0051i	0.0000 - 0.0004i
-0.0190 - 0.0237i	-0.0051 + 0.0009i	0.0003 - 0.0003i
0.0204 + 0.0256i	0.0000 - 0.0000i	-0.0004 - 0.0044i
0.0035 + 0.0045i	0.0067 - 0.0012i	0.0024 + 0.0309i
-0.0122 - 0.0156i	0.0110 - 0.0017i	-0.0002 - 0.0039i
0.0182 + 0.0235i	-0.0553 + 0.0092i	0.0003 + 0.0011i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.3218	0.4662	96.9118	0.5029	0.3554	0.0635
2	11.6478	0.3407	97.2582	0.8320	0.7025	**Modal Density**
3	10.2183	0.3519	96.5014	0.5731	0.4166	2.6564
4	12.4722	0.3032	98.7528	0.7677	0.9288	**File Name**
5	14.5375	0.2638	83.4351	0.6668	0.4137	analy_yellow_15
6	17.8248	0.2343	68.5559	0.4159	0.1794	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 15

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



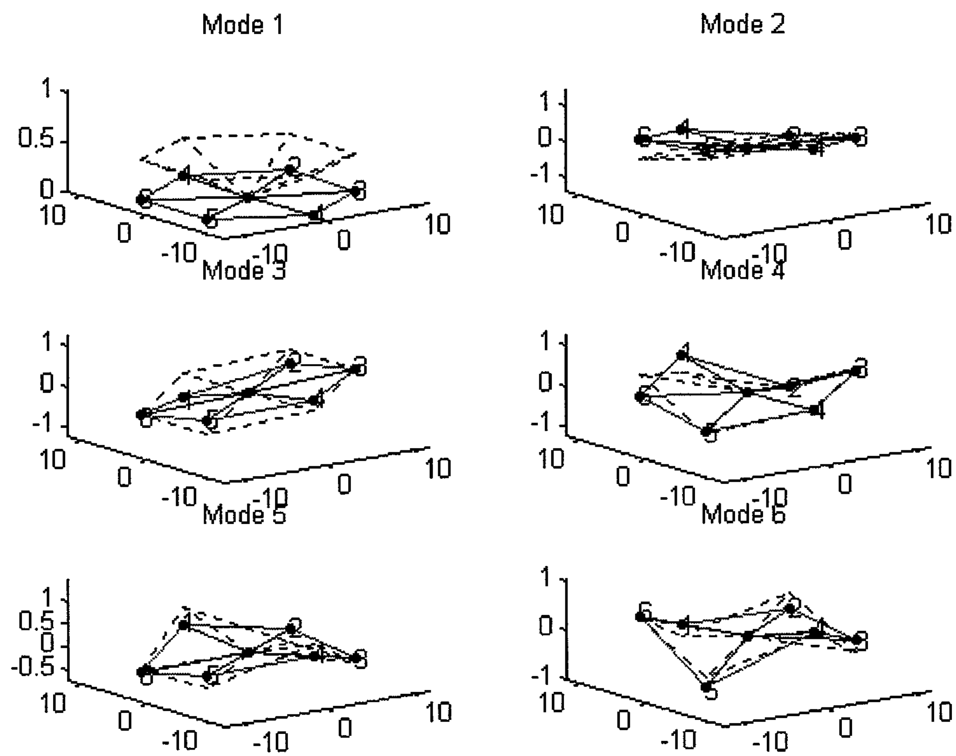
Mode 1	Mode2	Mode 3
0.0041 - 0.0070i	-0.0152 + 0.0028i	-0.0011 - 0.0201i
0.0094 - 0.0145i	-0.0489 + 0.0079i	-0.0003 + 0.0004i
0.0102 - 0.0165i	-0.0148 + 0.0025i	0.0007 + 0.0169i
0.0191 - 0.0312i	0.0208 - 0.0039i	0.0010 + 0.0206i
0.0117 - 0.0191i	0.0157 - 0.0022i	-0.0005 - 0.0302i
0.0067 - 0.0112i	0.0001 + 0.0013i	-0.0019 - 0.0501i
Mode 4	**Mode 5**	**Mode 6**
0.0080 - 0.0004i	0.0045 - 0.0267i	-0.0391 + 0.0031i
-0.0387 - 0.0013i	0.0007 - 0.0091i	0.0083 - 0.0003i
0.0611 + 0.0029i	-0.0062 + 0.0412i	-0.0023 + 0.0003i
-0.0074 - 0.0012i	0.0046 - 0.0309i	0.0013 + 0.0001i
-0.0433 + 0.0002i	-0.0093 + 0.0516i	-0.0039 + 0.0004i
0.0440 + 0.0010i	0.0044 - 0.0226i	0.0134 - 0.0010i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 16

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.6668	0.2529	98.0572	0.5852	0.5467	0.0082
2	10.8422	0.3948	95.7024	0.7014	0.5129	**Modal Density**
3	11.3977	0.4216	94.4076	0.6719	0.6802	1.7552
4	13.3773	0.2696	98.9491	0.7824	0.8935	**File Name**
5	13.6338	0.2505	98.4189	0.9084	0.9382	analy_yellow_16
6	16.0456	0.3299	89.0323	0.4430	0.2274	



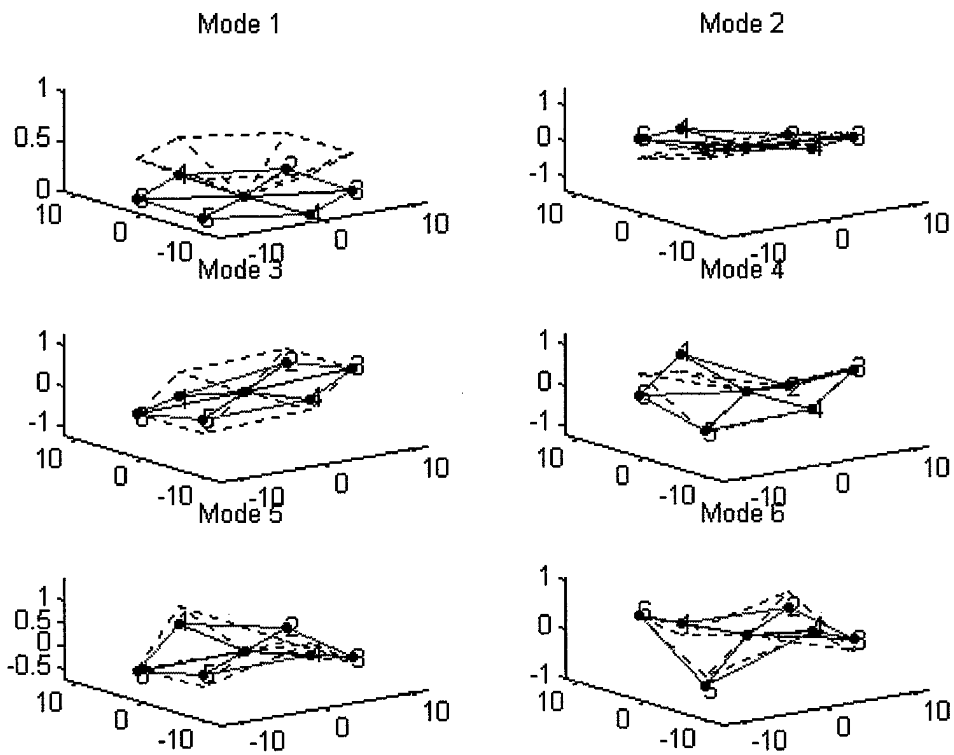
Mode 1	Mode2	Mode 3
0.0248 - 0.0101i	-0.0185 + 0.0268i	-0.0100 + 0.0322i
0.0317 - 0.0128i	-0.0240 + 0.0350i	0.0029 - 0.0097i
0.0299 - 0.0113i	0.0055 - 0.0080i	0.0109 - 0.0358i
0.0196 - 0.0071i	0.0243 - 0.0351i	0.0035 - 0.0118i
0.0155 - 0.0060i	0.0263 - 0.0377i	-0.0052 + 0.0180i
0.0199 - 0.0077i	0.0119 - 0.0169i	-0.0136 + 0.0454i
Mode 4	**Mode 5**	**Mode 6**
0.0008 + 0.0015i	0.0032 + 0.0551i	-0.0060 + 0.0049i
-0.0350 - 0.0286i	-0.0028 - 0.0424i	0.0042 - 0.0044i
0.0325 + 0.0262i	0.0006 + 0.0036i	-0.0064 + 0.0056i
-0.0325 - 0.0264i	0.0015 + 0.0338i	0.0225 - 0.0205i
-0.0337 - 0.0283i	-0.0007 - 0.0118i	-0.0256 + 0.0232i
0.0323 + 0.0258i	-0.0013 - 0.0343i	0.0108 - 0.0103i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2232	0.5662	98.7973	0.7617	0.8139	0.2529
2	11.8243	0.3680	99.3301	1.0755	1.0849	**Modal Density**
3	11.2634	0.2875	98.8267	0.7739	0.8578	1.2246
4	13.5307	0.2698	95.5977	1.0606	1.2446	**File Name**
5	13.8201	0.3142	97.6621	0.8957	0.8799	analy_yellow_17
6	15.2479	0.2492	98.3083	0.5927	0.4490	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 17

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



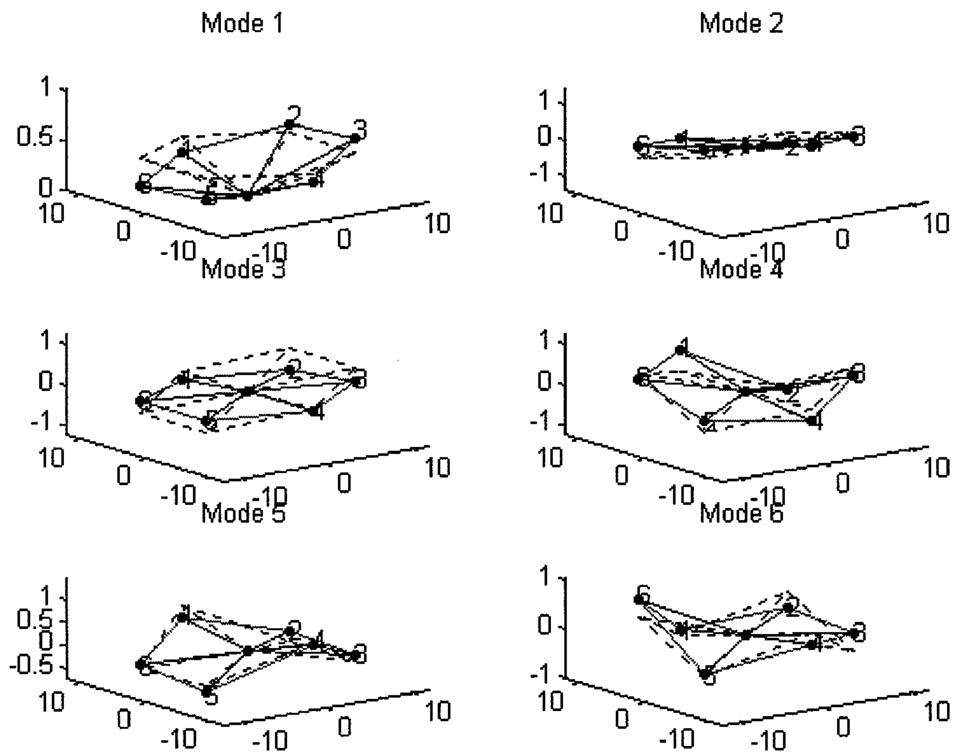
Mode 1	Mode2	Mode 3
0.0021 + 0.0287i	-0.0063 - 0.0032i	-0.0496 + 0.0120i
0.0039 + 0.0454i	-0.0280 - 0.0168i	0.0106 - 0.0030i
0.0019 + 0.0255i	0.0109 + 0.0068i	0.0394 - 0.0099i
0.0013 + 0.0163i	0.0389 + 0.0243i	0.0233 - 0.0052i
0.0008 + 0.0123i	0.0426 + 0.0263i	-0.0109 + 0.0033i
0.0011 + 0.0153i	0.0224 + 0.0142i	-0.0405 + 0.0104i
Mode 4	Mode 5	Mode 6
0.0396 + 0.0254i	0.0138 - 0.0202i	-0.0074 - 0.0036i
-0.0393 - 0.0247i	0.0006 - 0.0007i	0.0039 + 0.0013i
0.0398 + 0.0252i	-0.0142 + 0.0205i	-0.0075 - 0.0037i
0.0019 + 0.0012i	0.0246 - 0.0354i	0.0201 + 0.0093i
-0.0412 - 0.0268i	-0.0003 + 0.0009i	-0.0260 - 0.0115i
-0.0038 - 0.0028i	-0.0260 + 0.0374i	0.0202 + 0.0097i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 18

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1602	0.5299	97.8523	0.5818	0.5314	0.0242
2	11.7123	0.3746	99.0791	0.9361	0.8786	**Modal Density**
3	11.8244	0.4079	98.9305	0.8094	0.9013	1.3318
4	13.5663	0.2713	98.8693	0.9679	1.0043	**File Name**
5	14.3129	0.2283	93.0201	0.9103	0.7814	analy_yellow_18
6	15.5151	0.2662	94.3114	0.6351	0.5518	



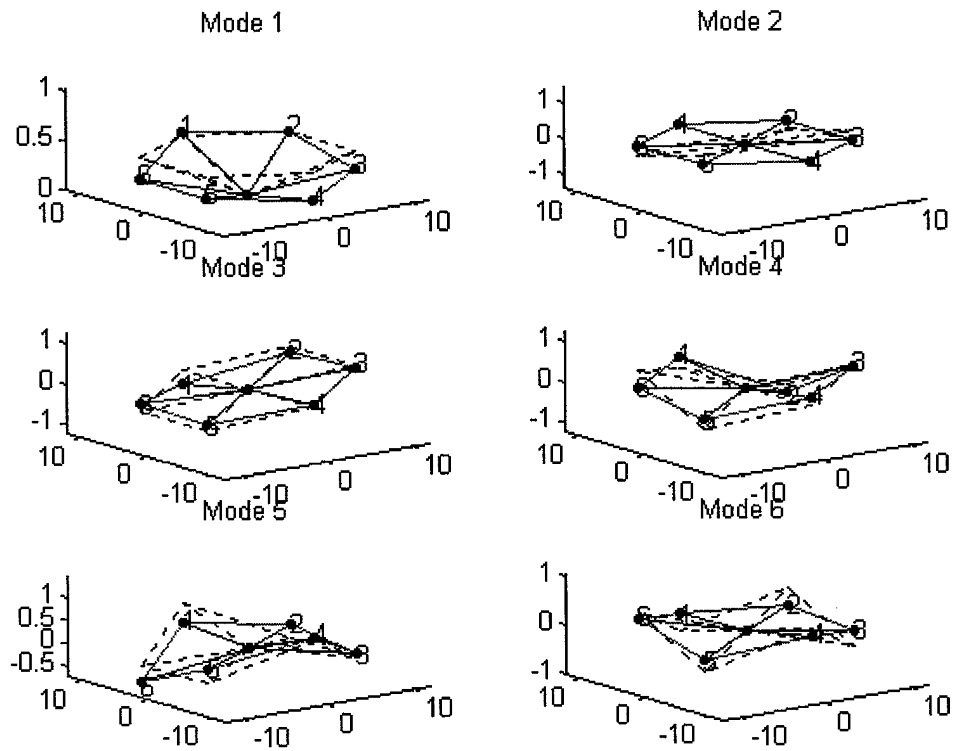
Mode 1	Mode2	Mode 3
0.0149 + 0.0082i	-0.0317 + 0.0007i	-0.0149 - 0.0383i
0.0314 + 0.0169i	-0.0508 + 0.0017i	-0.0037 - 0.0094i
0.0338 + 0.0191i	0.0127 - 0.0002i	0.0121 + 0.0310i
0.0208 + 0.0122i	0.0478 - 0.0009i	-0.0023 - 0.0070i
0.0123 + 0.0072i	0.0431 - 0.0009i	-0.0151 - 0.0403i
0.0084 + 0.0046i	0.0045 - 0.0000i	-0.0142 - 0.0368i
Mode 4	**Mode 5**	**Mode 6**
0.0425 - 0.0178i	0.0184 + 0.0137i	-0.0119 - 0.0059i
-0.0438 + 0.0194i	-0.0039 - 0.0026i	0.0033 + 0.0019i
0.0243 - 0.0105i	-0.0083 - 0.0066i	-0.0012 - 0.0009i
-0.0211 + 0.0088i	0.0340 + 0.0262i	0.0065 + 0.0034i
-0.0170 + 0.0075i	-0.0248 - 0.0189i	-0.0139 - 0.0068i
0.0285 - 0.0121i	-0.0136 - 0.0105i	0.0292 + 0.0143i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 19

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.4043	0.4499	97.7541	0.6604	0.5948	0.2644
2	12.0149	0.3663	98.4441	1.0110	0.9556	**Modal Density**
3	12.2569	0.3770	99.1342	0.9264	1.0173	1.5095
4	14.0296	0.2894	99.4518	0.8697	1.0412	**File Name**
5	14.7273	0.2779	99.5054	0.8259	0.7537	analy_yellow_19
6	16.4818	0.3083	91.8386	0.4935	0.3289	



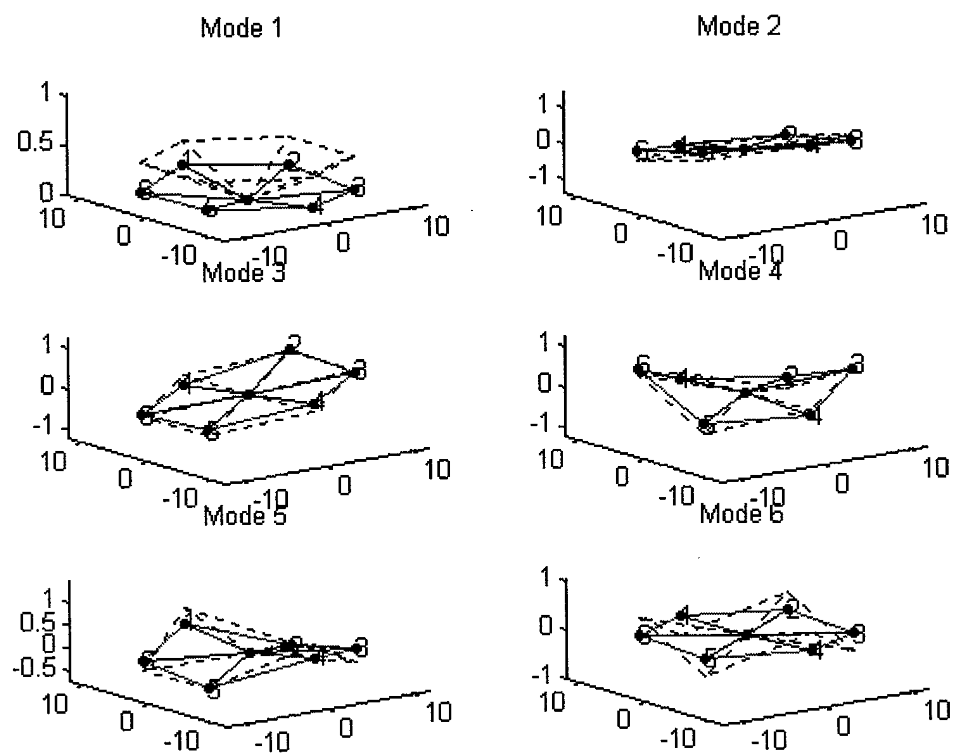
Mode 1	Mode2	Mode 3
0.0264 + 0.0261i	-0.0019 - 0.0286i	-0.0272 - 0.0208i
0.0244 + 0.0237i	-0.0008 - 0.0127i	0.0270 + 0.0211i
0.0143 + 0.0141i	0.0015 + 0.0172i	0.0359 + 0.0282i
0.0089 + 0.0087i	0.0020 + 0.0322i	0.0055 + 0.0041i
0.0116 + 0.0112i	0.0031 + 0.0554i	-0.0259 - 0.0209i
0.0118 + 0.0115i	0.0004 + 0.0098i	-0.0221 - 0.0173i
Mode 4	Mode 5	Mode 6
0.0258 + 0.0117i	0.0070 + 0.0025i	-0.0027 - 0.0048i
-0.0621 - 0.0285i	0.0010 - 0.0001i	0.0011 + 0.0036i
0.0411 + 0.0187i	-0.0097 - 0.0035i	-0.0032 - 0.0066i
0.0198 + 0.0093i	0.0304 + 0.0115i	0.0104 + 0.0233i
-0.0226 - 0.0103i	0.0003 - 0.0003i	-0.0063 - 0.0124i
0.0035 + 0.0015i	-0.0327 - 0.0120i	0.0110 + 0.0218i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.3201	0.3913	99.0209	0.6624	0.6146	0.3096
2	11.5815	0.3856	98.7287	0.7711	0.6640	**Modal Density**
3	11.7774	0.3624	98.9153	0.8753	1.1366	1.4982
4	13.6325	0.2454	97.7834	0.6791	0.6821	**File Name**
5	15.6041	0.2646	87.8512	0.8174	0.5687	analy_yellow_20
6	16.3117	0.2629	97.0068	0.6276	0.4803	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 20

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



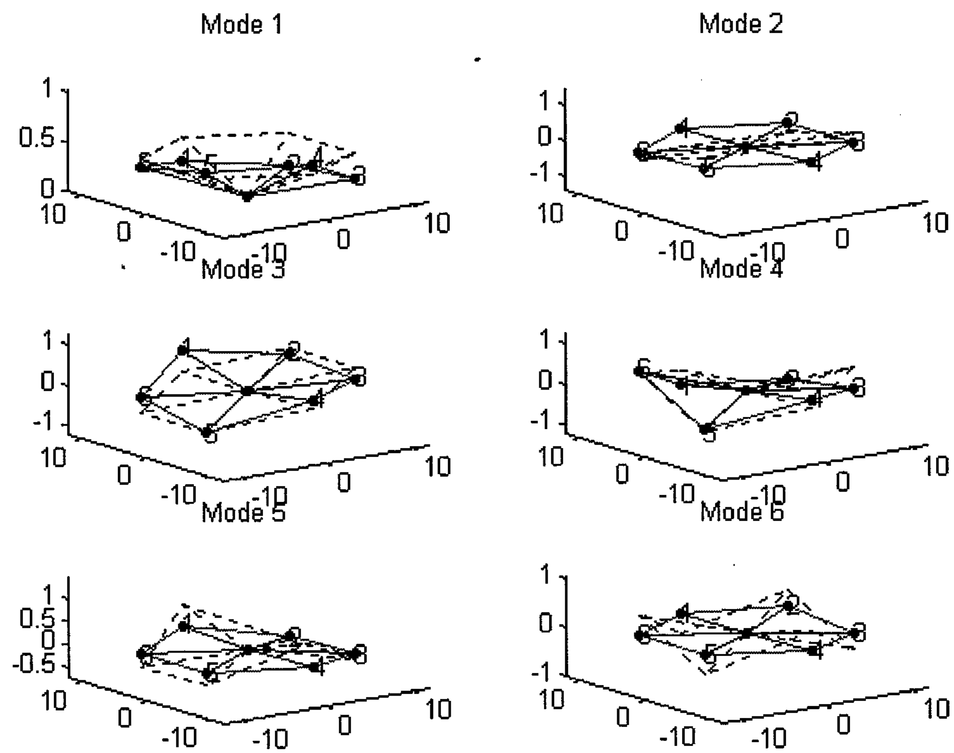
Mode 1	Mode2	Mode 3
0.0110 - 0.0335i	-0.0331 - 0.0135i	-0.0209 - 0.0084i
0.0087 - 0.0272i	-0.0213 - 0.0086i	0.0468 + 0.0169i
0.0051 - 0.0155i	0.0083 + 0.0031i	0.0371 + 0.0135i
0.0075 - 0.0229i	0.0402 + 0.0157i	0.0193 + 0.0079i
0.0080 - 0.0243i	0.0347 + 0.0137i	-0.0316 - 0.0107i
0.0071 - 0.0225i	-0.0007 - 0.0003i	-0.0367 - 0.0132i
Mode 4	**Mode 5**	**Mode 6**
-0.0101 + 0.0058i	0.0217 - 0.0325i	-0.0011 - 0.0105i
-0.0116 + 0.0063i	-0.0290 + 0.0435i	0.0014 + 0.0159i
0.0321 - 0.0164i	0.0028 - 0.0041i	-0.0027 - 0.0277i
-0.0083 + 0.0045i	0.0294 - 0.0436i	0.0020 + 0.0183i
-0.0167 + 0.0093i	-0.0275 + 0.0411i	-0.0020 - 0.0175i
0.0420 - 0.0219i	-0.0101 + 0.0152i	0.0025 + 0.0245i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 21

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1731	0.3958	98.6469	0.7433	0.8418	0.5803
2	11.0721	0.3747	93.3538	0.9587	0.9016	**Modal Density**
3	11.8806	0.3578	99.0027	0.8772	1.1543	1.2102
4	14.5323	0.2881	97.2749	0.6925	0.6704	**File Name**
5	13.2975	0.3052	98.5276	1.0881	1.0257	analy_yellow_21
6	15.1241	0.3493	98.1339	0.7174	0.7614	



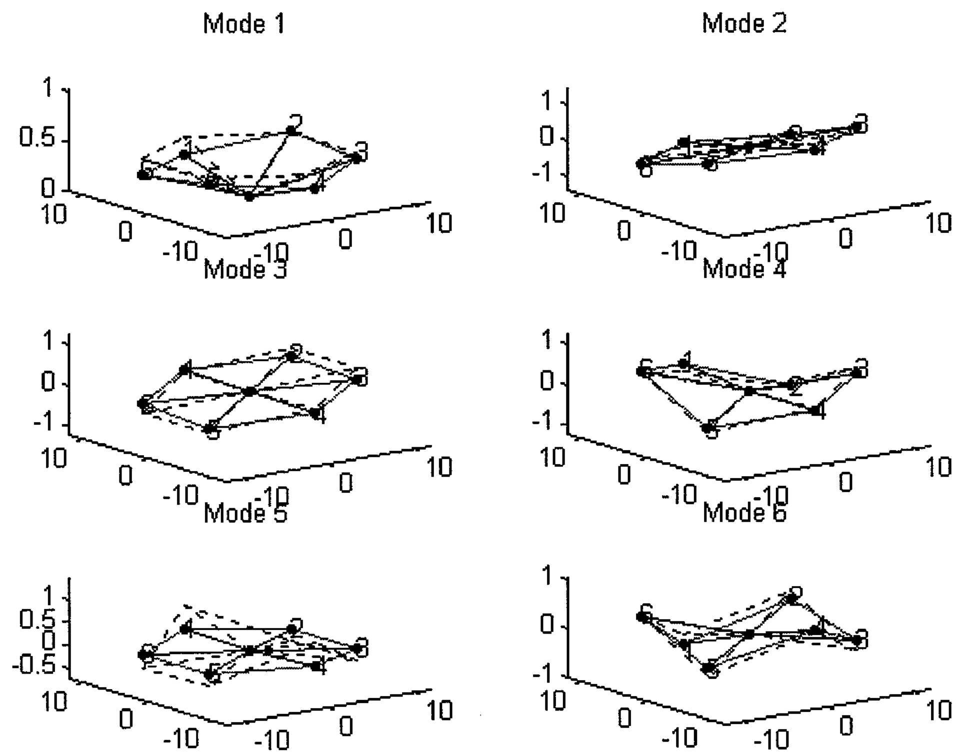
Mode 1	Mode2	Mode 3
0.0090 - 0.0063i	-0.0046 - 0.0297i	0.0435 - 0.0269i
0.0050 - 0.0038i	-0.0009 - 0.0072i	0.0299 - 0.0187i
0.0077 - 0.0060i	0.0010 + 0.0070i	0.0182 - 0.0115i
0.0281 - 0.0205i	0.0047 + 0.0320i	0.0198 - 0.0124i
0.0262 - 0.0193i	0.0001 - 0.0053i	-0.0419 + 0.0261i
0.0180 - 0.0127i	-0.0053 - 0.0386i	-0.0072 + 0.0045i
Mode 4	**Mode 5**	**Mode 6**
-0.0337 - 0.0207i	0.0073 + 0.0261i	-0.0008 - 0.0057i
-0.0296 - 0.0176i	-0.0135 - 0.0460i	0.0032 + 0.0275i
-0.0050 - 0.0031i	-0.0122 - 0.0424i	-0.0030 - 0.0262i
0.0202 + 0.0121i	0.0030 + 0.0108i	0.0006 + 0.0043i
-0.0454 - 0.0277i	-0.0004 - 0.0011i	0.0004 - 0.0009i
0.0510 + 0.0311i	-0.0024 - 0.0085i	0.0001 + 0.0014i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 22

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.6018	0.4119	98.1321	0.6441	0.5306	0.0869
2	10.7816	0.4212	96.5135	0.8884	0.7668	**Modal Density**
3	11.9582	0.3000	99.1003	0.8400	0.9167	2.0832
4	13.1758	0.3127	98.9868	0.8260	0.9516	**File Name**
5	14.4665	0.3593	93.9915	0.8667	0.6978	analy_yellow_22
6	16.8597	0.3960	86.9810	0.5744	0.3574	



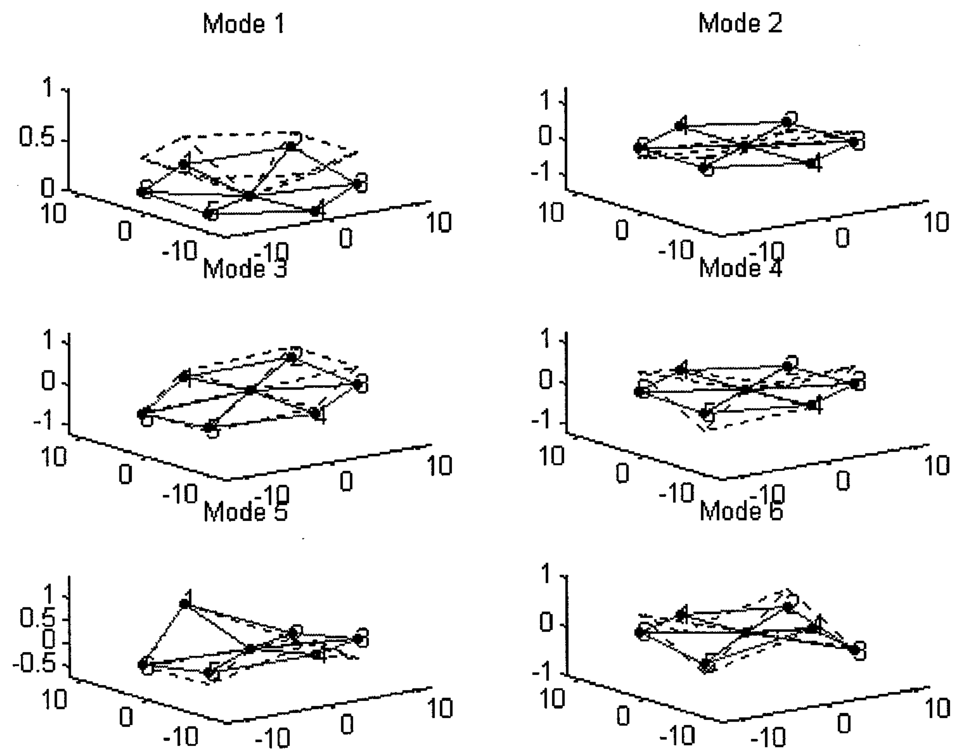
Mode 1	Mode2	Mode 3
0.0127 - 0.0098i	-0.0373 + 0.0056i	0.0015 - 0.0020i
0.0236 - 0.0181i	-0.0265 + 0.0039i	0.0210 - 0.0273i
0.0194 - 0.0151i	0.0352 - 0.0049i	0.0123 - 0.0164i
0.0159 - 0.0119i	0.0333 - 0.0047i	-0.0065 + 0.0083i
0.0198 - 0.0149i	0.0102 - 0.0017i	-0.0264 + 0.0348i
0.0139 - 0.0111i	-0.0362 + 0.0052i	-0.0160 + 0.0209i
Mode 4	**Mode 5**	**Mode 6**
0.0183 - 0.0094i	0.0036 + 0.0382i	-0.0345 + 0.0126i
-0.0416 + 0.0226i	-0.0004 - 0.0068i	0.0133 - 0.0050i
0.0351 - 0.0192i	-0.0020 - 0.0157i	-0.0102 + 0.0036i
-0.0021 + 0.0014i	0.0054 + 0.0543i	0.0245 - 0.0080i
-0.0377 + 0.0203i	-0.0016 - 0.0158i	-0.0138 + 0.0046i
0.0519 - 0.0277i	-0.0014 - 0.0136i	0.0216 - 0.0077i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9407	0.3303	97.5808	0.7605	0.8507	0.7759
2	11.6631	0.3310	99.2678	1.1830	1.2384	**Modal Density**
3	10.7305	0.3611	96.4084	0.7529	0.8184	1.2217
4	12.9031	0.3012	98.3078	0.8312	0.9901	**File Name**
5	14.2931	0.2911	98.7696	0.7616	0.5998	analy_yellow_23
6	14.8171	0.3398	98.4456	0.6158	0.5952	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 23

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



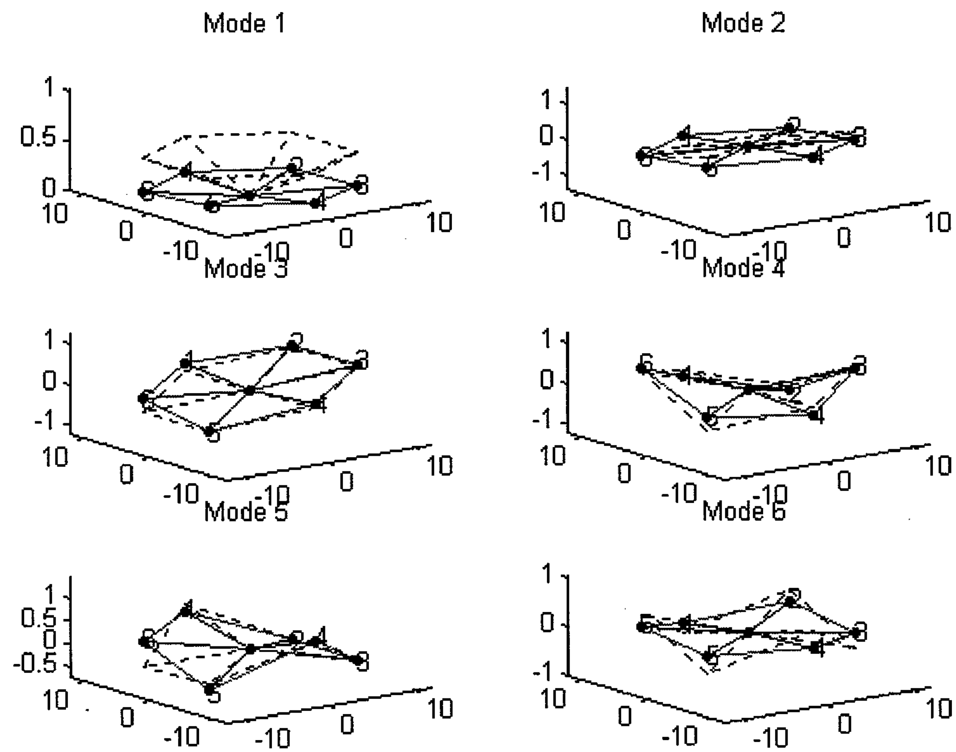
Mode 1	Mode2	Mode 3
0.0075 - 0.0203i	-0.0001 - 0.0449i	-0.0122 - 0.0109i
0.0166 - 0.0475i	0.0002 + 0.0032i	0.0164 + 0.0143i
0.0048 - 0.0135i	0.0004 + 0.0321i	0.0018 + 0.0017i
0.0026 - 0.0067i	0.0003 + 0.0628i	-0.0107 - 0.0093i
0.0033 - 0.0068i	-0.0001 + 0.0589i	-0.0287 - 0.0249i
0.0050 - 0.0126i	0.0000 - 0.0320i	-0.0391 - 0.0341i
Mode 4	Mode 5	Mode 6
-0.0010 - 0.0114i	0.0360 - 0.0361i	-0.0014 + 0.0016i
-0.0004 - 0.0053i	-0.0098 + 0.0101i	0.0021 - 0.0025i
0.0037 + 0.0352i	0.0085 - 0.0091i	-0.0155 + 0.0174i
0.0024 + 0.0205i	0.0174 - 0.0179i	0.0161 - 0.0189i
-0.0026 - 0.0345i	-0.0013 + 0.0029i	-0.0066 + 0.0074i
0.0016 + 0.0182i	-0.0172 + 0.0170i	0.0015 - 0.0020i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.0679	0.2986	97.1721	0.4800	0.3042	0.3182
2	12.9066	0.3782	97.1638	0.9851	0.9780	**Modal Density**
3	11.3421	0.4269	96.9185	0.6871	0.6684	1.8238
4	14.9683	0.5081	97.4377	0.8204	0.8576	**File Name**
5	14.5062	0.2312	98.0575	0.7315	0.5763	analy_yellow_24
6	16.9181	0.2890	92.2368	0.5884	0.3984	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 24

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40



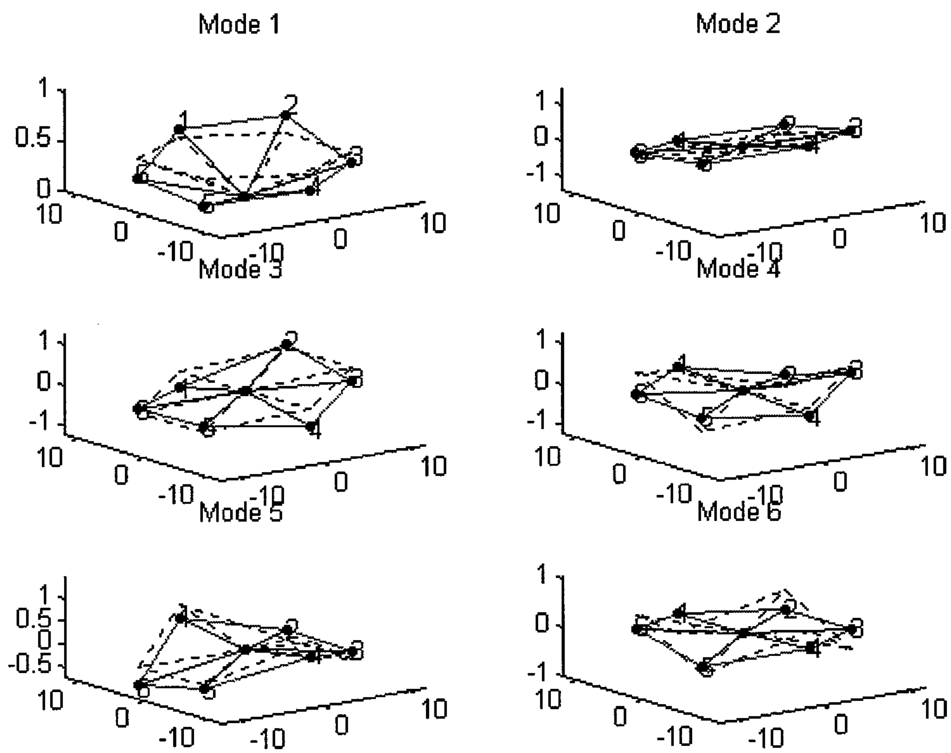
Mode 1	Mode2	Mode 3
0.0024 - 0.0126i	-0.0243 + 0.0481i	0.0136 - 0.0048i
0.0030 - 0.0138i	-0.0136 + 0.0277i	0.0375 - 0.0142i
0.0040 - 0.0194i	0.0065 - 0.0125i	0.0387 - 0.0148i
0.0072 - 0.0339i	0.0184 - 0.0366i	0.0075 - 0.0028i
0.0085 - 0.0401i	-0.0009 + 0.0018i	-0.0342 + 0.0127i
0.0042 - 0.0195i	-0.0195 + 0.0386i	-0.0111 + 0.0044i
Mode 4	Mode 5	Mode 6
-0.0102 + 0.0028i	0.0333 + 0.0122i	-0.0102 + 0.0279i
-0.0431 + 0.0122i	-0.0235 - 0.0084i	0.0077 - 0.0219i
0.0317 - 0.0091i	-0.0265 - 0.0093i	-0.0032 + 0.0095i
-0.0130 + 0.0033i	0.0526 + 0.0191i	0.0018 - 0.0053i
-0.0106 + 0.0031i	-0.0356 - 0.0128i	-0.0023 + 0.0071i
0.0436 - 0.0121i	0.0208 + 0.0079i	0.0082 - 0.0223i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 25

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1448	0.4025	97.8138	0.6330	0.5852	0.5112
2	12.0022	0.3679	98.5414	0.9337	0.9208	**Modal Density**
3	11.5233	0.3504	98.1538	0.8590	0.8724	1.3521
4	14.3031	0.3267	98.1414	0.8236	0.8158	**File Name**
5	13.7158	0.3186	99.3415	0.9073	1.0169	analy_yellow_25
6	15.5585	0.3378	96.1492	0.6406	0.5617	



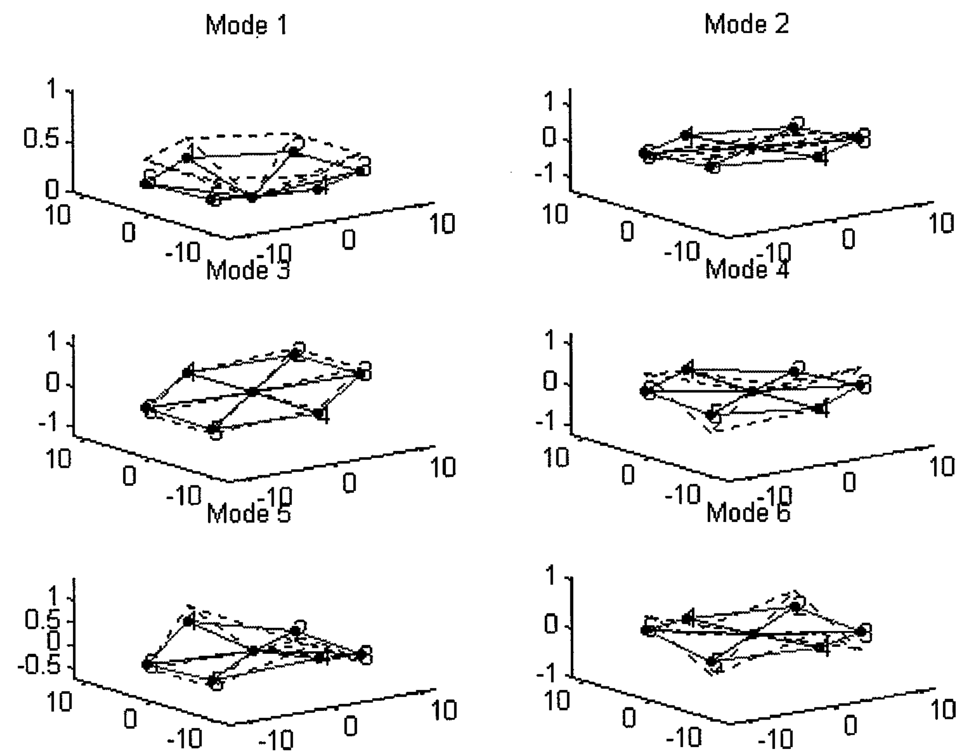
Mode 1	Mode2	Mode 3
0.0253 + 0.0123i	-0.0256 - 0.0205i	-0.0296 + 0.0065i
0.0315 + 0.0138i	-0.0044 - 0.0024i	0.0417 - 0.0100i
0.0167 + 0.0072i	0.0214 + 0.0170i	0.0108 - 0.0025i
0.0136 + 0.0062i	0.0316 + 0.0266i	-0.0323 + 0.0073i
0.0070 + 0.0034i	0.0081 + 0.0070i	-0.0237 + 0.0053i
0.0112 + 0.0053i	-0.0081 - 0.0061i	-0.0285 + 0.0062i
Mode 4	**Mode 5**	**Mode 6**
0.0088 - 0.0174i	0.0239 + 0.0142i	-0.0006 + 0.0034i
-0.0186 + 0.0350i	-0.0038 - 0.0024i	0.0001 - 0.0002i
0.0297 - 0.0567i	-0.0095 - 0.0057i	-0.0005 + 0.0024i
-0.0163 + 0.0301i	0.0232 + 0.0142i	0.0022 - 0.0067i
-0.0119 + 0.0229i	-0.0356 - 0.0223i	-0.0096 + 0.0349i
-0.0027 + 0.0056i	-0.0662 - 0.0413i	0.0052 - 0.0184i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.3946	0.2073	93.6964	0.6222	0.5675	0.0594
2	10.4880	0.3421	95.5688	0.8583	0.7647	**Modal Density**
3	11.1790	0.2153	97.7519	0.8578	1.1258	1.9915
4	12.8213	0.3051	98.8469	0.6952	0.7395	**File Name**
5	13.5286	0.3801	96.9663	0.7215	0.5467	analy_yellow_26
6	16.2487	0.2886	78.3335	0.4709	0.2734	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 26

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



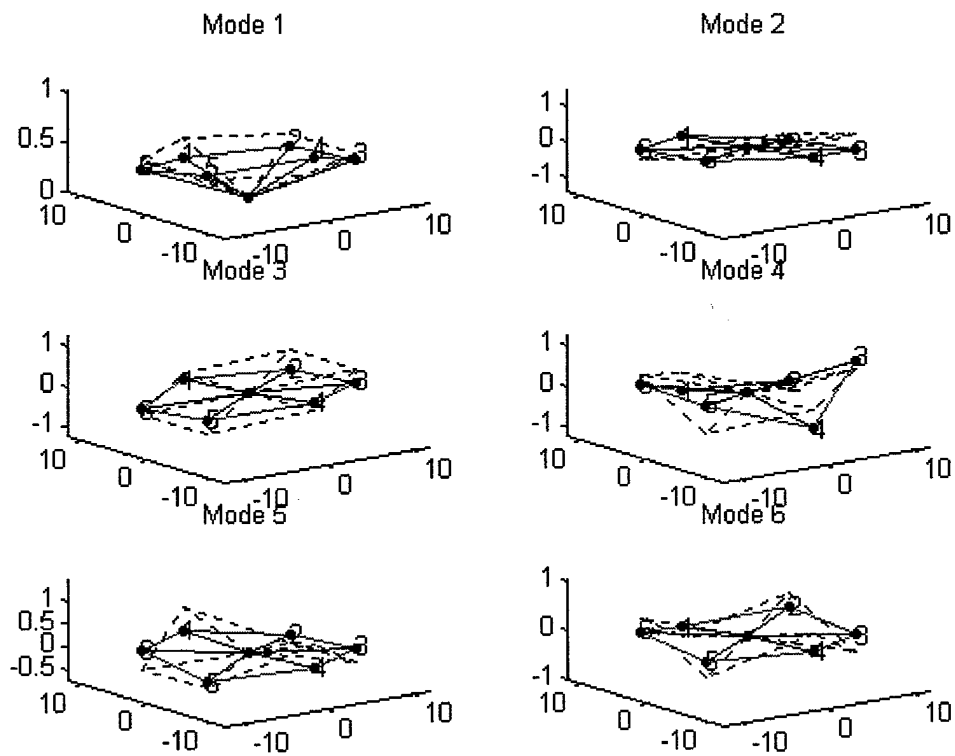
Mode 1	Mode2	Mode 3
0.0112 + 0.0167i	-0.0169 + 0.0379i	-0.0018 + 0.0021i
0.0123 + 0.0163i	-0.0074 + 0.0175i	0.0269 - 0.0259i
0.0125 + 0.0180i	0.0054 - 0.0121i	0.0266 - 0.0254i
0.0151 + 0.0236i	0.0139 - 0.0318i	-0.0076 + 0.0074i
0.0111 + 0.0176i	0.0046 - 0.0113i	-0.0306 + 0.0290i
0.0098 + 0.0149i	-0.0079 + 0.0178i	-0.0268 + 0.0251i
Mode 4	Mode 5	Mode 6
0.0028 + 0.0190i	0.0191 - 0.0388i	-0.0057 + 0.0229i
-0.0099 - 0.0702i	-0.0057 + 0.0093i	0.0060 - 0.0247i
0.0053 + 0.0376i	-0.0143 + 0.0305i	-0.0043 + 0.0164i
0.0008 + 0.0041i	0.0225 - 0.0458i	0.0051 - 0.0205i
-0.0066 - 0.0459i	-0.0140 + 0.0270i	-0.0095 + 0.0378i
0.0044 + 0.0333i	-0.0195 + 0.0402i	0.0096 - 0.0383i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.7405	0.4297	96.0755	0.7772	0.9121	0.8202
2	10.7441	0.4218	98.3188	0.8790	0.8392	**Modal Density**
3	11.1488	0.3537	97.3368	0.9175	1.0244	1.1107
4	13.3386	0.3015	99.5648	0.7099	0.7691	**File Name**
5	12.8587	0.3135	99.3783	1.0523	1.1385	analy_yellow_27
6	14.1514	0.2161	99.0520	0.7319	0.7299	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 27

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



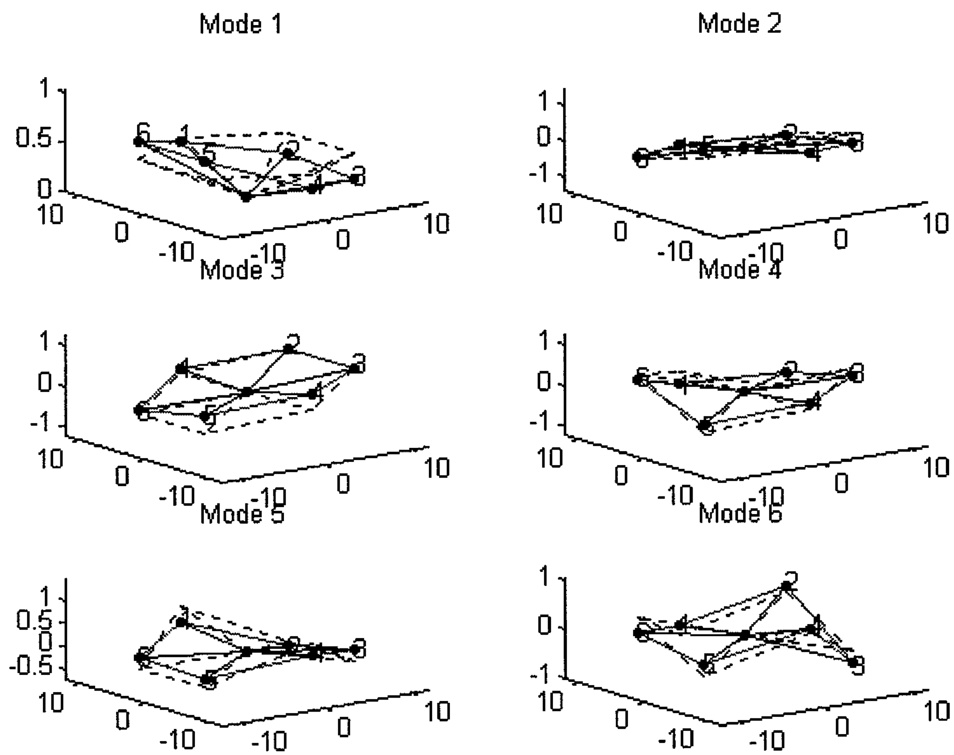
Mode 1	Mode2	Mode 3
0.0124 - 0.0032i	-0.0175 - 0.0206i	-0.0126 - 0.0209i
0.0180 - 0.0048i	-0.0349 - 0.0413i	-0.0006 + 0.0047i
0.0207 - 0.0061i	-0.0133 - 0.0163i	0.0100 + 0.0212i
0.0358 - 0.0112i	0.0170 + 0.0191i	0.0130 + 0.0219i
0.0272 - 0.0084i	0.0175 + 0.0201i	-0.0090 - 0.0204i
0.0181 - 0.0055i	-0.0008 + 0.0000i	-0.0222 - 0.0426i
Mode 4	Mode 5	Mode 6
-0.0414 + 0.0004i	0.0060 + 0.0260i	-0.0122 - 0.0395i
-0.0251 - 0.0011i	-0.0098 - 0.0375i	0.0059 + 0.0220i
0.0612 + 0.0008i	0.0036 + 0.0131i	-0.0035 - 0.0119i
-0.0381 - 0.0000i	0.0058 + 0.0253i	0.0022 + 0.0072i
0.0180 - 0.0011i	-0.0162 - 0.0657i	-0.0040 - 0.0125i
0.0217 + 0.0011i	0.0097 + 0.0385i	0.0072 + 0.0227i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 28

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.0358	0.2792	97.9937	0.6492	0.6725	0.0411
2	11.3207	0.4046	96.0313	0.7888	0.7297	**Modal Density**
3	11.4336	0.4268	99.0284	0.7075	0.8027	1.1971
4	13.6117	0.2791	99.4982	0.7457	0.8772	**File Name**
5	13.5227	0.2591	98.9634	0.8194	0.7969	analy_yellow_28
6	14.8757	0.3571	97.7901	0.5568	0.4720	



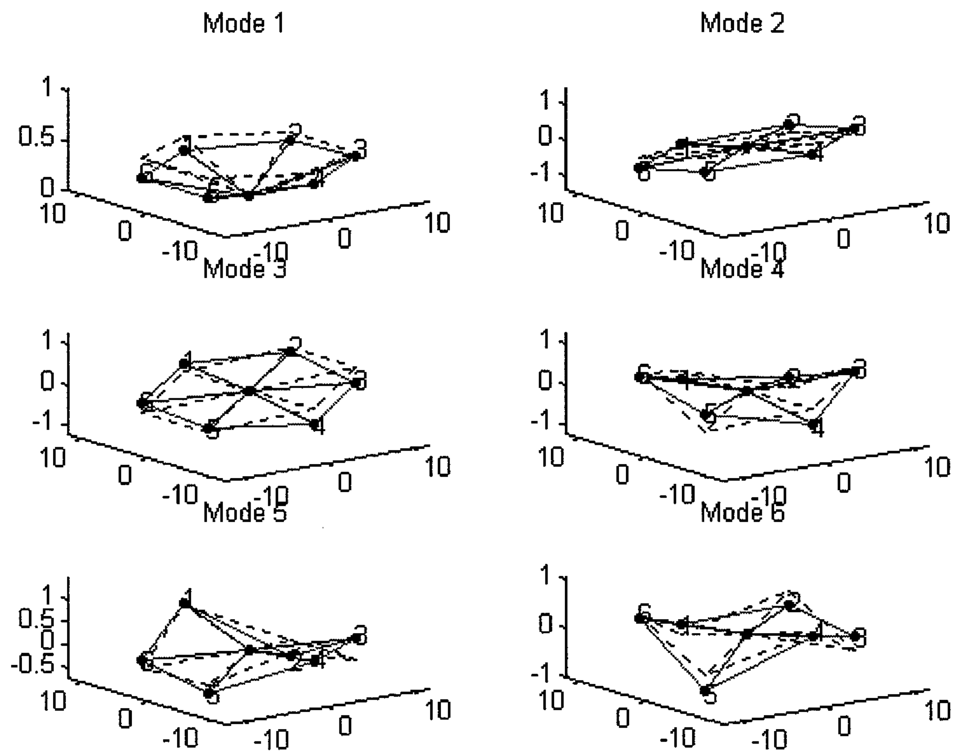
Mode 1	Mode2	Mode 3
0.0208 + 0.0044i	-0.0378 - 0.0186i	0.0077 - 0.0038i
0.0117 + 0.0019i	-0.0222 - 0.0125i	0.0433 - 0.0204i
0.0083 + 0.0017i	0.0009 - 0.0008i	0.0416 - 0.0206i
0.0162 + 0.0037i	0.0235 + 0.0104i	0.0321 - 0.0152i
0.0333 + 0.0074i	0.0366 + 0.0175i	-0.0033 + 0.0018i
0.0336 + 0.0074i	-0.0160 - 0.0069i	-0.0327 + 0.0156i
Mode 4	**Mode 5**	**Mode 6**
-0.0314 + 0.0360i	0.0176 - 0.0268i	-0.0087 - 0.0004i
-0.0067 + 0.0088i	-0.0267 + 0.0388i	0.0243 + 0.0007i
0.0274 - 0.0318i	-0.0024 + 0.0036i	-0.0283 + 0.0010i
0.0169 - 0.0194i	0.0258 - 0.0376i	0.0227 - 0.0017i
-0.0274 + 0.0316i	-0.0088 + 0.0129i	-0.0070 + 0.0005i
0.0334 - 0.0388i	-0.0033 + 0.0059i	0.0039 + 0.0004i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 29

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9595	0.4136	97.3980	0.6799	0.5888	0.4041
2	11.4172	0.3133	96.0657	0.9719	0.9317	**Modal Density**
3	11.8710	0.3521	96.3740	0.8807	0.9556	1.4286
4	13.4722	0.2887	98.9846	0.9371	1.1314	**File Name**
5	14.1456	0.3941	94.2343	0.9199	0.7659	analy_yellow_29
6	15.5208	0.7169	94.1809	0.6527	0.5528	



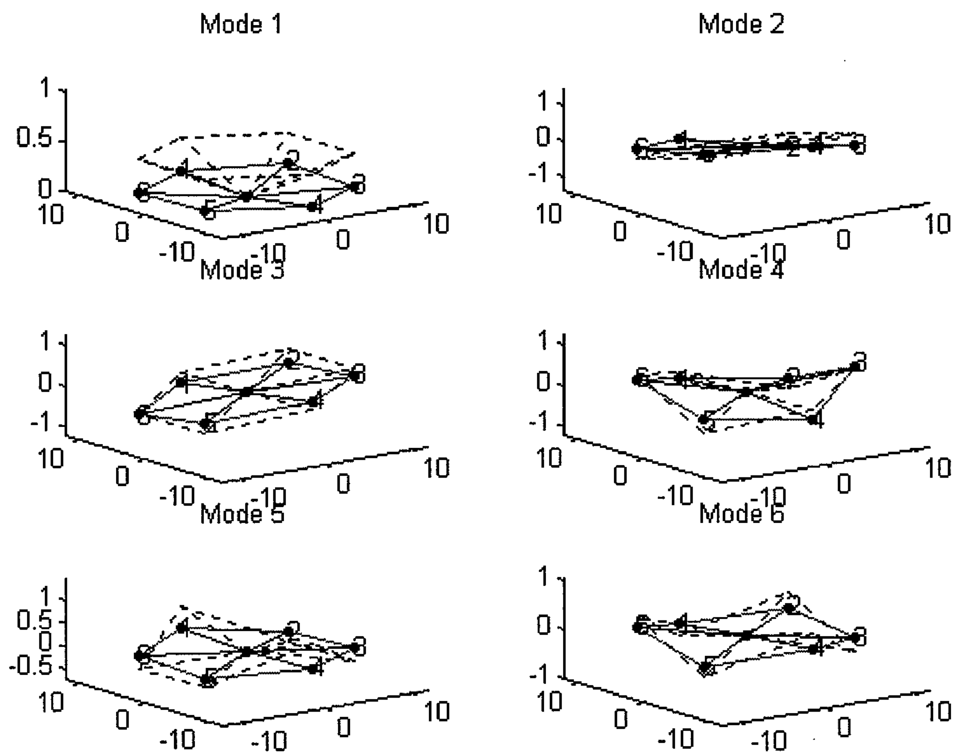
Mode 1	Mode2	Mode 3
0.0165 + 0.0158i	-0.0402 + 0.0139i	0.0132 + 0.0111i
0.0217 + 0.0207i	-0.0044 + 0.0010i	0.0290 + 0.0262i
0.0234 + 0.0224i	0.0306 - 0.0111i	0.0074 + 0.0073i
0.0206 + 0.0202i	0.0242 - 0.0080i	-0.0270 - 0.0242i
0.0136 + 0.0132i	-0.0093 + 0.0034i	-0.0271 - 0.0248i
0.0142 + 0.0133i	-0.0430 + 0.0152i	-0.0158 - 0.0150i
Mode 4	**Mode 5**	**Mode 6**
-0.0226 - 0.0189i	0.0534 + 0.0018i	-0.0122 - 0.0052i
-0.0241 - 0.0206i	-0.0565 - 0.0019i	0.0078 + 0.0035i
0.0360 + 0.0312i	0.0173 + 0.0003i	-0.0078 - 0.0033i
-0.0383 - 0.0336i	0.0155 + 0.0007i	0.0193 + 0.0081i
-0.0058 - 0.0054i	-0.0387 - 0.0013i	-0.0390 - 0.0178i
0.0392 + 0.0342i	-0.0131 - 0.0008i	0.0208 + 0.0094i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1132	0.4490	98.4230	0.8020	0.8655	0.1712
2	11.2108	0.3754	98.3798	0.9572	0.8927	**Modal Density**
3	11.5377	0.3785	98.2395	0.9113	1.0368	1.1685
4	13.2419	0.2663	99.0561	0.9377	1.0768	**File Name**
5	13.7327	0.2993	98.2771	0.9287	0.8211	analy_yellow_30
6	14.8927	0.2102	95.1396	0.5317	0.4171	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 30

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



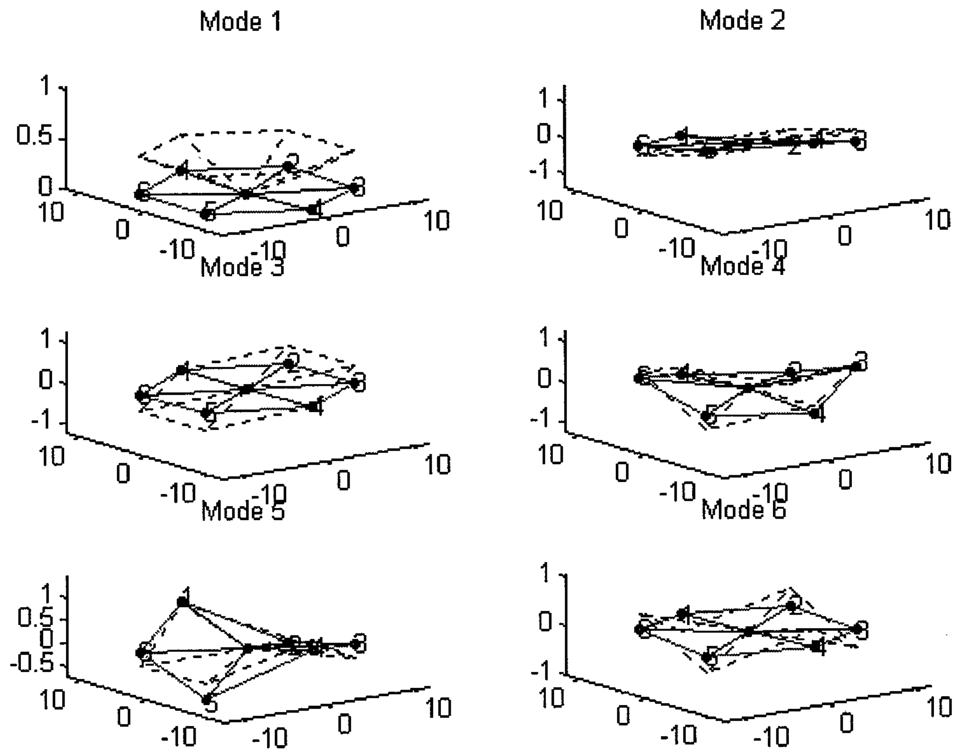
Mode 1	Mode2	Mode 3
0.0038 + 0.0165i	-0.0220 + 0.0078i	-0.0203 - 0.0211i
0.0057 + 0.0242i	-0.0372 + 0.0132i	0.0124 + 0.0124i
0.0038 + 0.0184i	-0.0024 + 0.0009i	0.0202 + 0.0195i
0.0056 + 0.0266i	0.0326 - 0.0112i	0.0150 + 0.0159i
0.0044 + 0.0202i	0.0247 - 0.0085i	-0.0172 - 0.0172i
0.0035 + 0.0155i	0.0015 - 0.0007i	-0.0344 - 0.0351i
Mode 4	**Mode 5**	**Mode 6**
-0.0156 + 0.0137i	0.0092 + 0.0602i	-0.0113 + 0.0287i
-0.0208 + 0.0193i	-0.0057 - 0.0364i	0.0063 - 0.0173i
0.0508 - 0.0460i	0.0002 + 0.0020i	-0.0076 + 0.0209i
-0.0197 + 0.0173i	0.0055 + 0.0358i	0.0070 - 0.0187i
-0.0146 + 0.0138i	-0.0093 - 0.0597i	-0.0126 + 0.0321i
0.0345 - 0.0313i	-0.0006 - 0.0026i	0.0136 - 0.0349i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 31

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.8684	0.5074	98.2450	0.7769	0.8643	0.3532
2	10.8076	0.3339	94.0791	0.9225	0.8613	**Modal Density**
3	11.2873	0.4515	98.3390	0.7499	0.9393	1.0854
4	13.4055	0.2920	98.5779	0.6996	0.7483	**File Name**
5	13.1115	0.2606	98.4885	0.9506	0.8221	analy_yellow_31
6	14.2510	0.2123	98.7987	0.7531	0.7908	



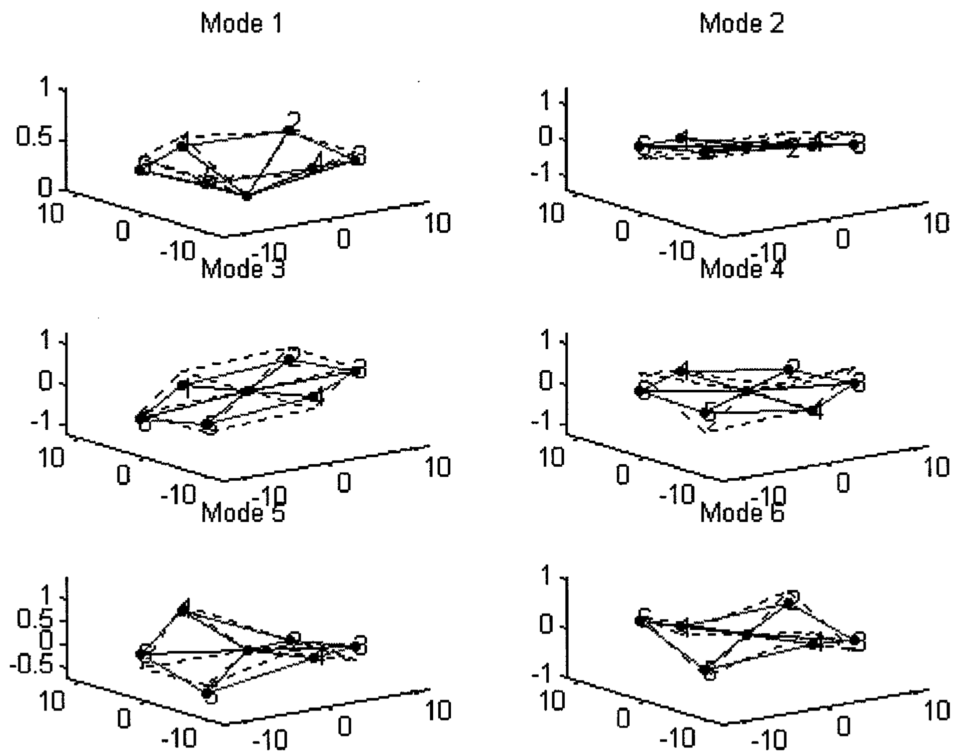
Mode 1	Mode2	Mode 3
0.0025 + 0.0169i	-0.0225 + 0.0044i	-0.0027 + 0.0290i
0.0030 + 0.0241i	-0.0379 + 0.0074i	0.0022 - 0.0173i
0.0016 + 0.0184i	-0.0027 + 0.0005i	0.0025 - 0.0279i
0.0019 + 0.0265i	0.0327 - 0.0062i	0.0022 - 0.0218i
0.0019 + 0.0203i	0.0249 - 0.0043i	-0.0028 + 0.0244i
0.0023 + 0.0160i	0.0015 - 0.0000i	-0.0050 + 0.0486i
Mode 4	Mode 5	Mode 6
-0.0135 + 0.0163i	0.0602 + 0.0052i	-0.0046 - 0.0302i
-0.0175 + 0.0224i	-0.0367 - 0.0028i	0.0032 + 0.0186i
0.0428 - 0.0525i	0.0016 + 0.0003i	-0.0041 - 0.0219i
-0.0166 + 0.0200i	0.0365 + 0.0031i	0.0034 + 0.0197i
-0.0123 + 0.0160i	-0.0603 - 0.0050i	-0.0054 - 0.0333i
0.0295 - 0.0360i	-0.0024 - 0.0001i	0.0061 + 0.0370i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 31

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.8713	0.7095	96.6555	0.7842	0.8769	0.3535
2	10.8087	0.3813	93.8080	0.9193	0.8619	**Modal Density**
3	11.2884	0.4543	98.9636	0.7523	0.9462	1.0866
4	13.4129	0.3060	98.8893	0.7038	0.7593	**File Name**
5	13.1123	0.2702	97.2219	0.9548	0.8261	analy_yellow_31r1
6	14.2594	0.1921	98.5197	0.7484	0.7966	



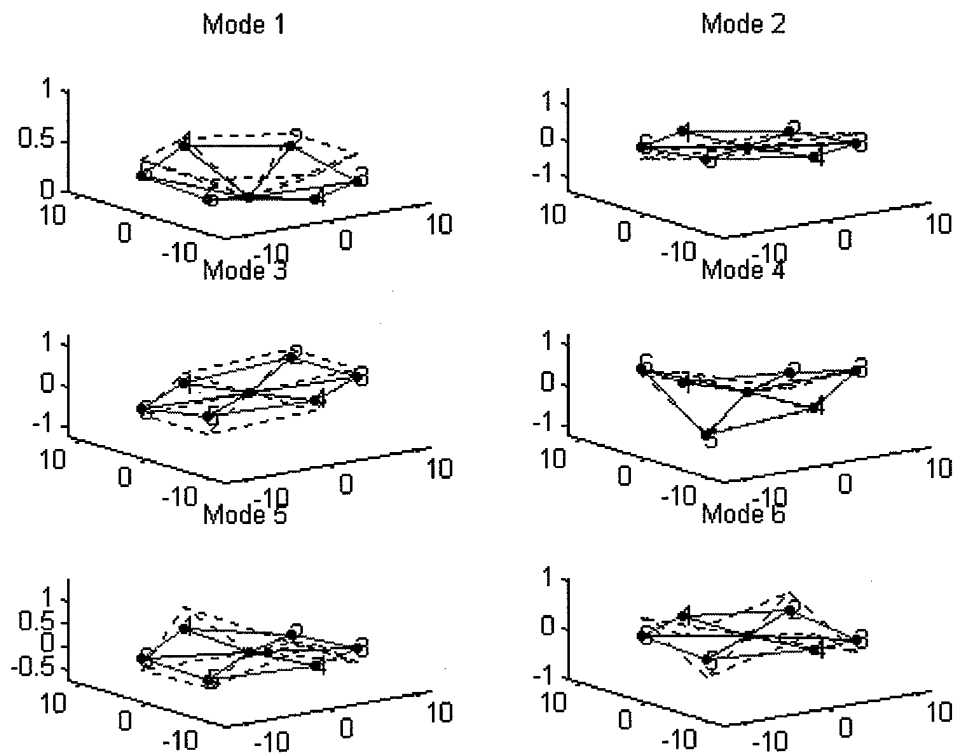
Mode 1	Mode2	Mode 3
0.0156 + 0.0075i	-0.0228 - 0.0006i	-0.0276 + 0.0095i
0.0227 + 0.0107i	-0.0393 - 0.0009i	0.0164 - 0.0056i
0.0167 + 0.0076i	-0.0033 + 0.0001i	0.0266 - 0.0099i
0.0243 + 0.0116i	0.0339 + 0.0016i	0.0209 - 0.0072i
0.0184 + 0.0087i	0.0266 + 0.0011i	-0.0230 + 0.0080i
0.0149 + 0.0068i	0.0025 + 0.0006i	-0.0460 + 0.0162i
Mode 4	Mode 5	Mode 6
-0.0024 - 0.0210i	0.0422 - 0.0423i	-0.0182 - 0.0249i
-0.0032 - 0.0277i	-0.0264 + 0.0263i	0.0113 + 0.0147i
0.0083 + 0.0671i	0.0025 - 0.0016i	-0.0135 - 0.0169i
-0.0028 - 0.0265i	0.0257 - 0.0262i	0.0122 + 0.0155i
-0.0022 - 0.0192i	-0.0429 + 0.0430i	-0.0199 - 0.0267i
0.0054 + 0.0463i	-0.0007 + 0.0014i	0.0222 + 0.0298i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.8504	0.6098	97.4302	0.7844	0.8710	0.3341
2	10.8007	0.3499	95.7615	0.9218	0.8661	**Modal Density**
3	11.2870	0.4312	98.9333	0.7543	0.9506	1.1043
4	13.4274	0.3147	99.0788	0.7039	0.7576	**File Name**
5	13.1356	0.2549	96.2380	0.9507	0.8317	analy_yellow_31r2
6	14.2891	0.1949	98.9688	0.7484	0.7922	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 31

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



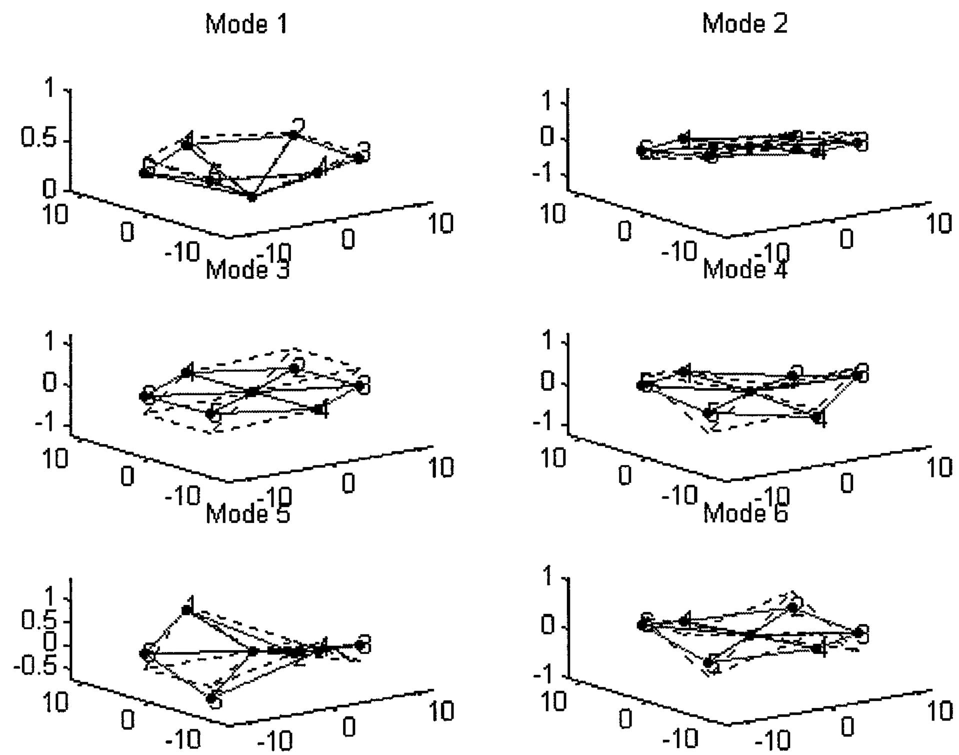
Mode 1	Mode2	Mode 3
0.0170 + 0.0235i	-0.0098 - 0.0186i	-0.0186 - 0.0216i
0.0162 + 0.0231i	-0.0147 - 0.0284i	0.0222 + 0.0246i
0.0075 + 0.0105i	0.0012 + 0.0029i	0.0190 + 0.0215i
0.0097 + 0.0128i	0.0164 + 0.0345i	0.0189 + 0.0227i
0.0109 + 0.0144i	0.0179 + 0.0377i	-0.0045 - 0.0042i
0.0134 + 0.0176i	0.0058 + 0.0127i	-0.0242 - 0.0270i
Mode 4	Mode 5	Mode 6
-0.0217 - 0.0010i	0.0106 + 0.0502i	-0.0012 + 0.0059i
-0.0076 + 0.0000i	-0.0088 - 0.0406i	0.0024 - 0.0138i
0.0357 + 0.0015i	0.0026 + 0.0123i	-0.0080 + 0.0397i
0.0068 + 0.0003i	0.0101 + 0.0487i	0.0047 - 0.0245i
-0.0471 - 0.0019i	-0.0085 - 0.0407i	-0.0030 + 0.0150i
0.0552 + 0.0024i	-0.0064 - 0.0310i	0.0017 - 0.0097i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.8562	0.5466	97.5236	0.7545	0.7749	0.1993
2	10.9458	0.3831	96.6894	0.9666	0.9218	**Modal Density**
3	11.3771	0.3794	98.4907	0.9703	1.2208	1.2697
4	13.8730	0.3416	98.3204	0.7645	0.7884	**File Name**
5	13.0140	0.2634	99.4918	1.1101	1.1788	analy_yellow_32
6	14.8489	0.2929	96.8131	0.5357	0.4180	

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 32

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



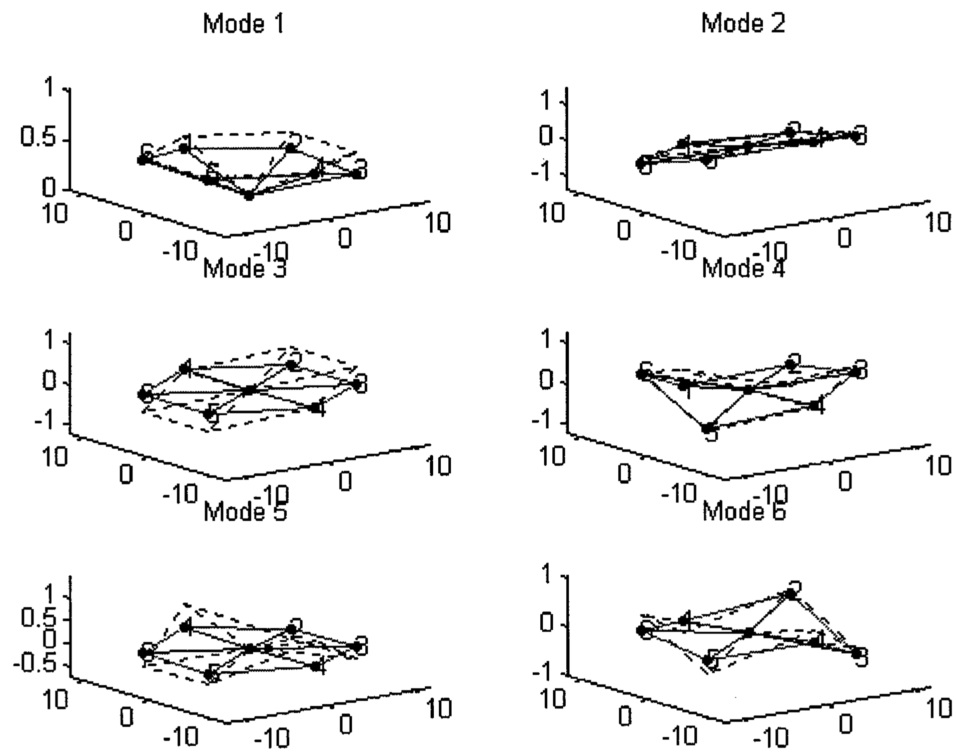
Mode 1	Mode2	Mode 3
0.0199 + 0.0104i	-0.0278 - 0.0237i	-0.0022 + 0.0330i
0.0240 + 0.0117i	-0.0308 - 0.0264i	0.0010 - 0.0213i
0.0215 + 0.0111i	-0.0014 - 0.0014i	0.0024 - 0.0405i
0.0265 + 0.0141i	0.0271 + 0.0232i	0.0014 - 0.0193i
0.0237 + 0.0126i	0.0266 + 0.0227i	-0.0019 + 0.0313i
0.0172 + 0.0089i	-0.0018 - 0.0014i	-0.0026 + 0.0416i
Mode 4	Mode 5	Mode 6
-0.0030 + 0.0068i	0.0454 - 0.0099i	-0.0070 - 0.0203i
-0.0140 + 0.0296i	-0.0493 + 0.0111i	0.0041 + 0.0121i
0.0224 - 0.0452i	0.0064 - 0.0016i	-0.0031 - 0.0093i
-0.0158 + 0.0327i	0.0411 - 0.0091i	0.0041 + 0.0117i
0.0001 - 0.0001i	-0.0487 + 0.0108i	-0.0067 - 0.0204i
0.0173 - 0.0348i	0.0022 - 0.0005i	0.0123 + 0.0371i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 33

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2413	0.4027	98.3412	0.8385	0.9338	0.3025
2	11.3035	0.4324	96.3950	1.0533	0.9889	**Modal Density**
3	11.6948	0.3508	99.3183	0.9520	1.2003	1.1616
4	13.9754	0.3212	88.2793	0.7997	0.9077	**File Name**
5	13.4979	0.2723	97.8662	1.0846	0.9918	analy_yellow_33
6	15.0571	0.2621	98.1046	0.5592	0.4853	



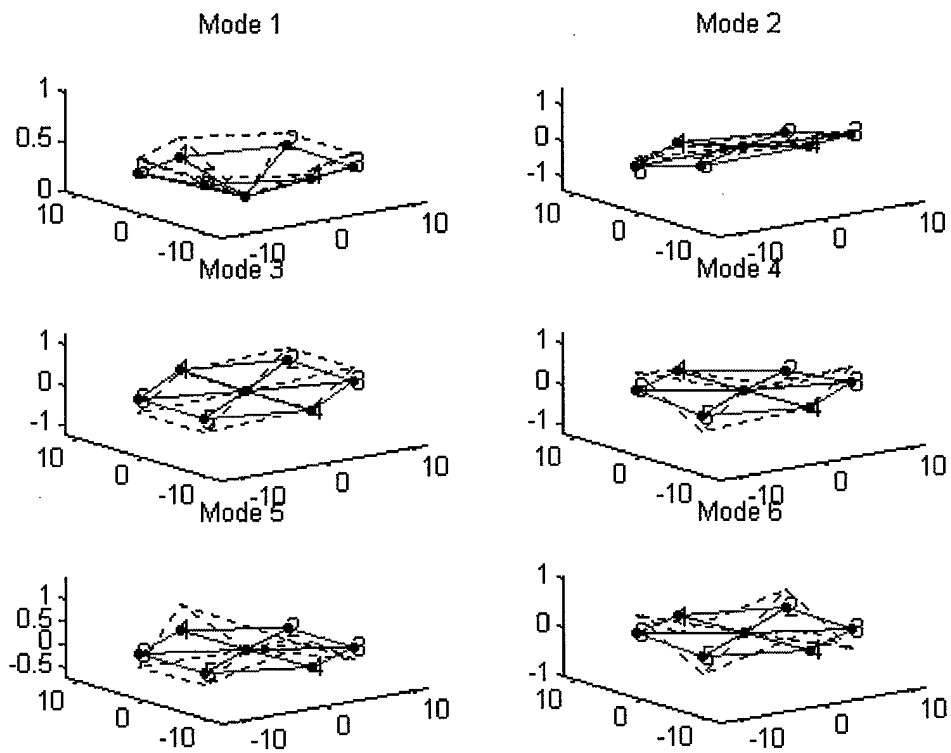
Mode 1	Mode2	Mode 3
0.0150 - 0.0103i	-0.0326 - 0.0016i	0.0018 + 0.0148i
0.0135 - 0.0089i	-0.0172 - 0.0010i	0.0051 + 0.0504i
0.0104 - 0.0073i	0.0100 - 0.0003i	0.0029 + 0.0264i
0.0225 - 0.0153i	0.0427 + 0.0016i	0.0005 + 0.0073i
0.0213 - 0.0147i	0.0131 + 0.0006i	-0.0026 - 0.0257i
0.0214 - 0.0155i	-0.0280 - 0.0009i	-0.0029 - 0.0325i
Mode 4	**Mode 5**	**Mode 6**
-0.0391 + 0.0254i	0.0060 + 0.0530i	-0.0086 - 0.0099i
0.0029 - 0.0017i	-0.0049 - 0.0458i	0.0170 + 0.0185i
0.0313 - 0.0207i	-0.0016 - 0.0122i	-0.0277 - 0.0310i
0.0048 - 0.0031i	0.0044 + 0.0402i	0.0103 + 0.0115i
-0.0422 + 0.0276i	-0.0059 - 0.0575i	-0.0061 - 0.0074i
0.0400 - 0.0263i	0.0001 + 0.0018i	0.0045 + 0.0051i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 34

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9321	0.4713	98.2303	0.8029	0.8086	0.3052
2	10.9688	0.3238	98.1317	0.8804	0.8642	**Modal Density**
3	11.3732	0.3429	99.0358	0.7170	0.7992	1.2484
4	13.6124	0.2535	99.0748	0.9123	0.9708	**File Name**
5	13.3129	0.2974	97.1177	1.0035	0.9637	analy_yellow_34
6	14.8929	0.2826	97.0958	0.5301	0.4057	



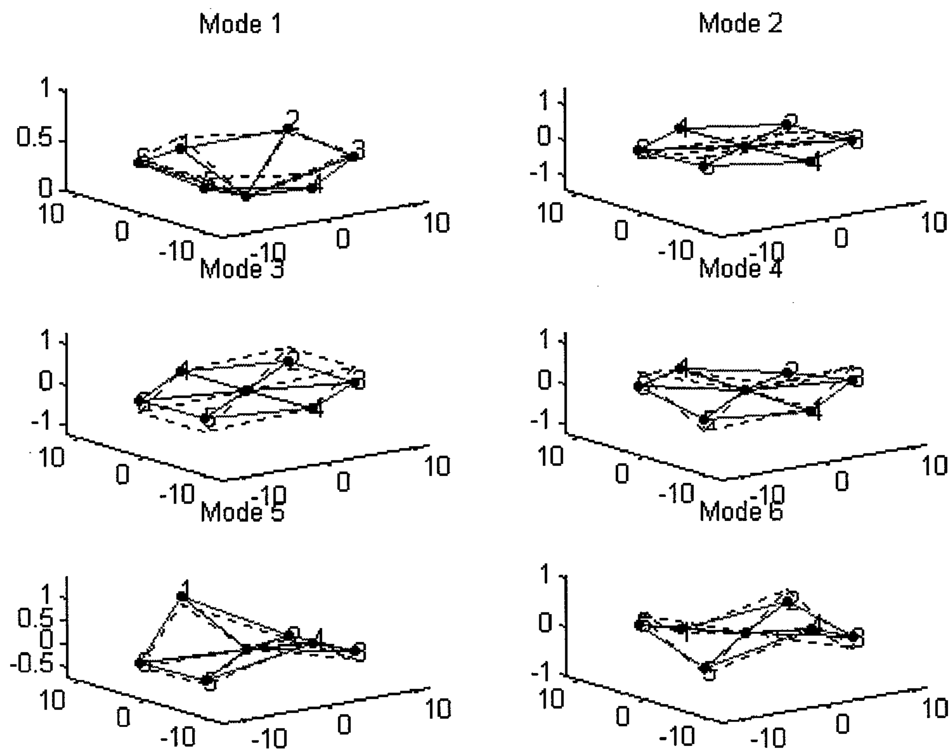
Mode 1	Mode2	Mode 3
0.0125 - 0.0120i	-0.0342 - 0.0119i	0.0019 + 0.0084i
0.0177 - 0.0164i	-0.0200 - 0.0068i	0.0139 + 0.0452i
0.0171 - 0.0158i	0.0178 + 0.0063i	0.0093 + 0.0282i
0.0228 - 0.0208i	0.0387 + 0.0136i	-0.0022 - 0.0088i
0.0219 - 0.0199i	0.0054 + 0.0020i	-0.0115 - 0.0369i
0.0172 - 0.0163i	-0.0378 - 0.0132i	-0.0091 - 0.0271i
Mode 4	**Mode 5**	**Mode 6**
0.0004 + 0.0042i	0.0019 - 0.0430i	-0.0037 + 0.0395i
-0.0077 - 0.0477i	-0.0001 + 0.0008i	0.0022 - 0.0217i
0.0072 + 0.0425i	-0.0012 + 0.0354i	-0.0011 + 0.0140i
0.0011 + 0.0075i	0.0019 - 0.0494i	0.0010 - 0.0119i
-0.0082 - 0.0520i	-0.0011 + 0.0329i	-0.0014 + 0.0150i
0.0071 + 0.0459i	-0.0001 + 0.0077i	0.0027 - 0.0222i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 35

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2499	0.4665	98.8886	0.8158	0.8936	0.7204
2	11.6433	0.3283	98.9755	1.0368	0.9900	**Modal Density**
3	11.3581	0.3543	98.6304	0.7897	0.8971	1.1312
4	13.5650	0.2619	99.3419	0.9103	0.9951	**File Name**
5	13.9188	0.2849	93.0303	0.9555	0.9216	analy_yellow_35
6	14.9633	0.3064	98.8228	0.5746	0.5285	



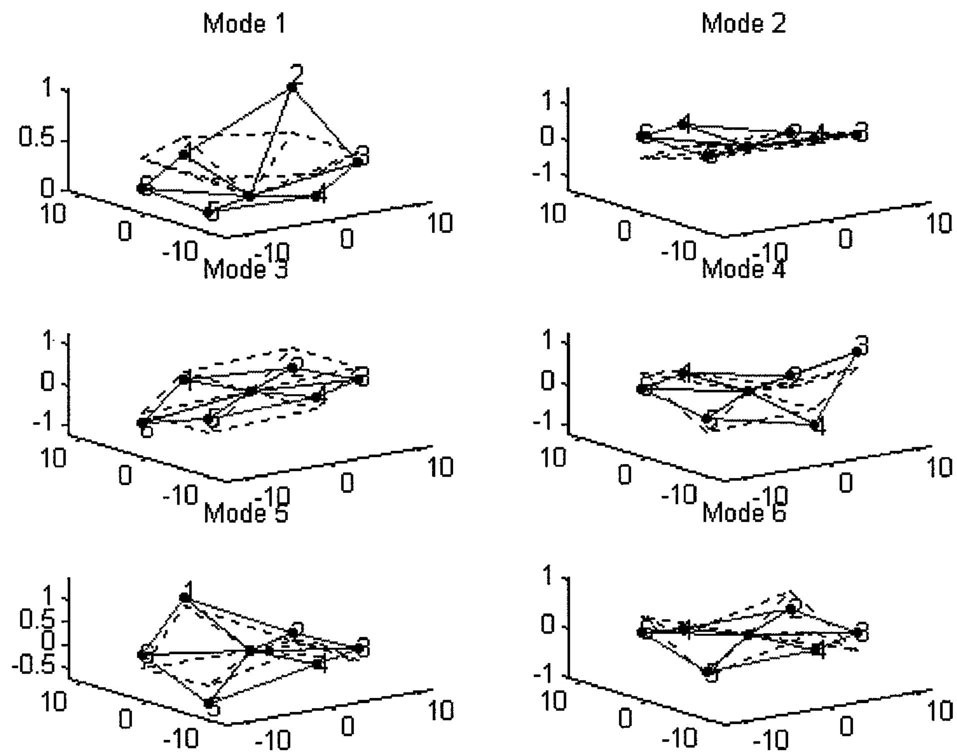
Mode 1	Mode2	Mode 3
0.0162 + 0.0099i	-0.0040 + 0.0297i	-0.0017 + 0.0065i
0.0259 + 0.0156i	-0.0040 + 0.0328i	0.0087 - 0.0288i
0.0206 + 0.0118i	0.0037 - 0.0270i	0.0072 - 0.0238i
0.0152 + 0.0094i	0.0053 - 0.0391i	-0.0001 + 0.0010i
0.0176 + 0.0105i	0.0037 - 0.0290i	-0.0086 + 0.0274i
0.0206 + 0.0122i	-0.0028 + 0.0180i	-0.0120 + 0.0383i
Mode 4	Mode 5	Mode 6
0.0027 - 0.0072i	0.0537 - 0.0006i	-0.0184 + 0.0178i
-0.0140 + 0.0394i	-0.0142 + 0.0006i	0.0081 - 0.0077i
0.0157 - 0.0438i	-0.0086 + 0.0002i	-0.0086 + 0.0086i
-0.0057 + 0.0162i	0.0398 - 0.0005i	0.0248 - 0.0238i
-0.0202 + 0.0555i	-0.0148 + 0.0004i	-0.0159 + 0.0155i
0.0142 - 0.0389i	-0.0153 + 0.0003i	0.0108 - 0.0102i

System Information
System: Yellow Band (40.70 N/m)
PZT Coupling: Off
Mistuning: Set 36

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.9461	0.4202	98.6418	0.7585	0.8755	0.8024
2	11.5821	0.3567	99.0838	1.0829	1.2895	**Modal Density**
3	10.7821	0.3777	92.5984	0.7887	0.8957	1.2376
4	12.9074	0.2840	99.4233	0.8238	0.9771	**File Name**
5	14.3432	0.3173	97.5625	0.7749	0.6149	analy_yellow_36
6	14.8781	0.2891	97.8966	0.6315	0.6171	



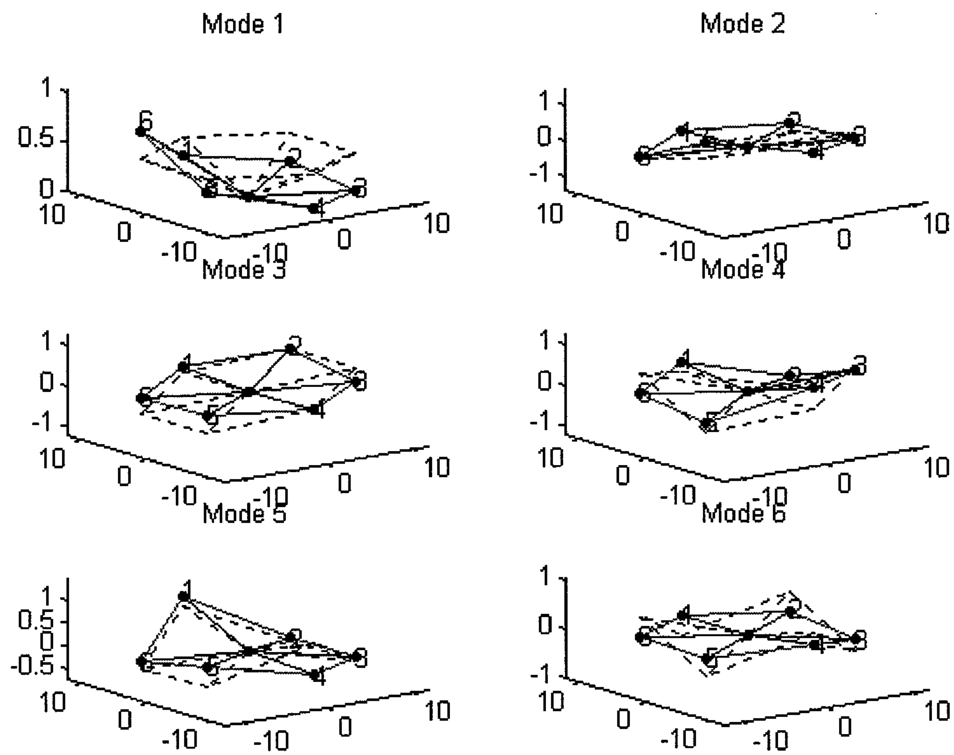
Mode 1	Mode2	Mode 3
0.0116 + 0.0027i	0.0012 + 0.0004i	-0.0153 - 0.0087i
0.0462 + 0.0105i	-0.0176 + 0.0027i	-0.0004 + 0.0000i
0.0169 + 0.0039i	0.0137 - 0.0023i	0.0135 + 0.0074i
0.0103 + 0.0028i	0.0450 - 0.0068i	0.0225 + 0.0124i
0.0038 + 0.0010i	0.0195 - 0.0023i	-0.0094 - 0.0056i
0.0060 + 0.0013i	0.0214 - 0.0014i	-0.0515 - 0.0295i
Mode 4	**Mode 5**	**Mode 6**
-0.0045 + 0.0003i	0.0430 + 0.0032i	-0.0129 + 0.0259i
-0.0188 + 0.0014i	-0.0049 - 0.0002i	0.0014 - 0.0033i
0.0821 - 0.0057i	-0.0005 - 0.0003i	-0.0012 + 0.0029i
-0.0366 + 0.0026i	0.0068 - 0.0001i	0.0024 - 0.0056i
-0.0156 + 0.0009i	-0.0370 - 0.0016i	-0.0147 + 0.0304i
0.0107 - 0.0010i	-0.0011 - 0.0003i	0.0045 - 0.0092i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 1

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.5770	0.2861	98.4906	0.4604	0.2630	0.1583
2	10.7684	0.3490	96.3729	0.7425	0.6131	**Modal Density**
3	11.1777	0.4611	87.3727	0.5868	0.4522	1.6893
4	13.0745	0.3445	98.8739	0.5716	0.4092	**File Name**
5	15.2975	0.2573	93.7889	0.7698	0.5108	analy_green_1
6	15.7056	0.3481	90.6659	0.5600	0.3801	



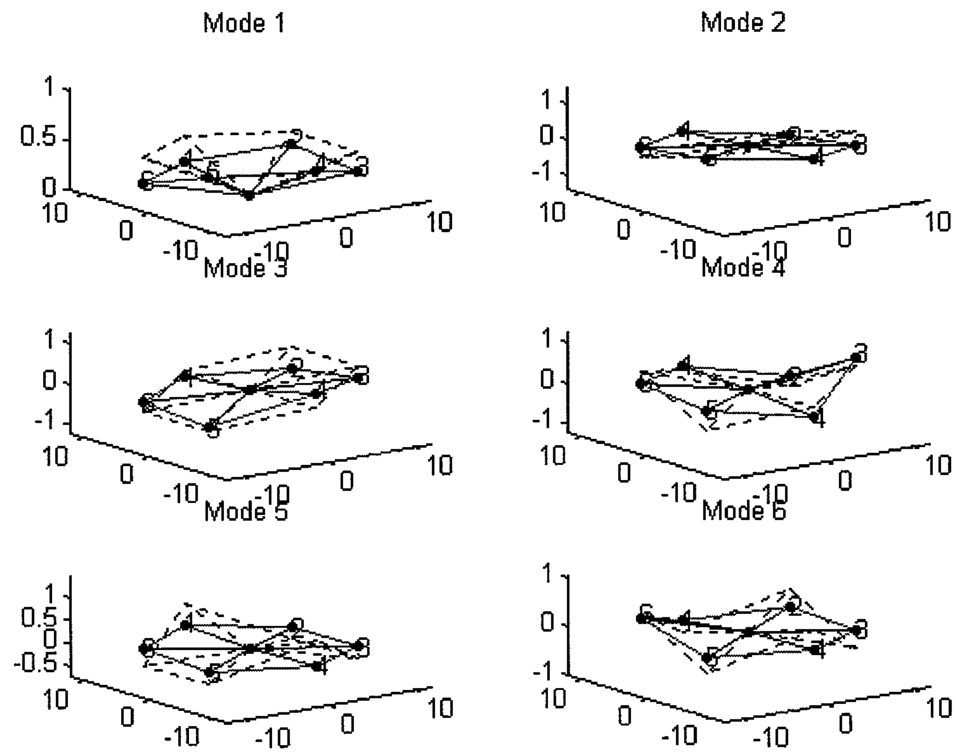
Mode 1	Mode2	Mode 3
0.0121 + 0.0083i	-0.0114 - 0.0065i	0.0097 - 0.0145i
0.0071 + 0.0047i	0.0003 + 0.0001i	0.0303 - 0.0480i
0.0021 + 0.0017i	0.0105 + 0.0057i	0.0082 - 0.0130i
0.0040 + 0.0031i	0.0299 + 0.0172i	0.0019 - 0.0030i
0.0144 + 0.0114i	0.0600 + 0.0348i	-0.0026 + 0.0043i
0.0361 + 0.0280i	-0.0170 - 0.0098i	-0.0058 + 0.0102i
Mode 4	**Mode 5**	**Mode 6**
0.0162 + 0.0109i	0.0662 + 0.0392i	-0.0003 + 0.0019i
-0.0141 - 0.0095i	-0.0154 - 0.0090i	0.0008 - 0.0047i
0.0312 + 0.0232i	-0.0177 - 0.0101i	-0.0070 + 0.0274i
0.0394 + 0.0292i	-0.0083 - 0.0050i	0.0065 - 0.0258i
-0.0160 - 0.0118i	0.0122 + 0.0067i	-0.0010 + 0.0055i
-0.0003 + 0.0001i	-0.0135 - 0.0078i	-0.0002 - 0.0005i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 2

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.6529	0.4322	94.7289	0.4682	0.2778	0.1503
2	12.1376	0.3932	88.7896	0.6812	0.4530	**Modal Density**
3	10.9122	0.3332	95.8179	0.5526	0.3671	1.9229
4	14.4253	0.3097	86.9501	0.7198	0.7341	**File Name**
5	13.9375	0.3172	97.8995	0.6362	0.3647	analy_green_2
6	16.5031	0.1851	92.3739	0.5709	0.3572	



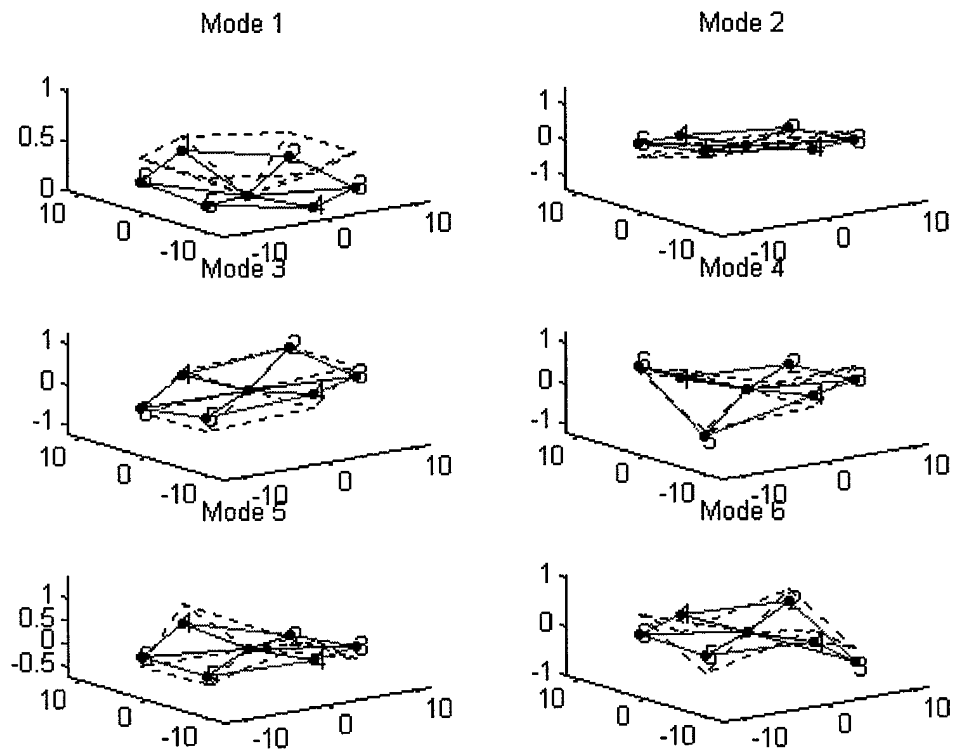
Mode 1	Mode2	Mode 3
0.0076 + 0.0072i	-0.0107 + 0.0171i	-0.0125 + 0.0160i
0.0152 + 0.0132i	-0.0252 + 0.0418i	-0.0032 + 0.0044i
0.0111 + 0.0112i	-0.0063 + 0.0100i	0.0141 - 0.0165i
0.0230 + 0.0211i	0.0092 - 0.0149i	0.0259 - 0.0295i
0.0216 + 0.0193i	0.0142 - 0.0223i	-0.0263 + 0.0315i
0.0081 + 0.0074i	0.0013 - 0.0018i	-0.0164 + 0.0202i
Mode 4	Mode 5	Mode 6
0.0070 + 0.0056i	0.0081 - 0.0568i	-0.0115 + 0.0291i
-0.0234 - 0.0196i	-0.0026 + 0.0209i	0.0030 - 0.0073i
0.0616 + 0.0522i	-0.0029 + 0.0108i	-0.0024 + 0.0055i
-0.0214 - 0.0178i	0.0027 - 0.0175i	0.0019 - 0.0036i
0.0013 + 0.0007i	-0.0031 + 0.0226i	-0.0053 + 0.0131i
0.0180 + 0.0154i	0.0037 - 0.0275i	0.0246 - 0.0585i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.5282	0.2749	97.2506	0.6801	0.6369	0.0064
2	10.1529	0.2449	96.6599	0.7421	0.6014	**Modal Density**
3	11.0531	0.3280	97.1390	0.8454	0.9562	1.2653
4	13.1797	0.3575	96.8030	0.5832	0.4440	**File Name**
5	12.3162	0.3363	97.3234	0.7443	0.6228	analy_green_3
6	14.3407	0.3101	97.9664	0.4693	0.2741	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 3

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



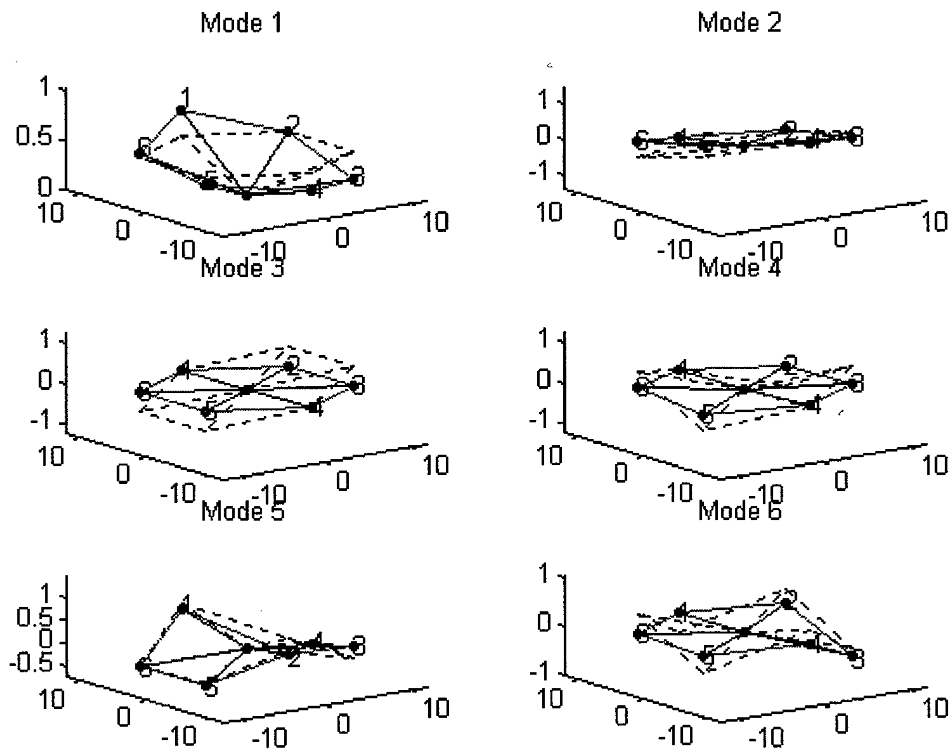
Mode 1	Mode2	Mode 3
0.0214 + 0.0477i	-0.0223 + 0.0222i	-0.0101 - 0.0085i
0.0132 + 0.0293i	-0.0152 + 0.0143i	0.0516 + 0.0426i
0.0044 + 0.0099i	0.0049 - 0.0053i	0.0266 + 0.0214i
0.0069 + 0.0161i	0.0340 - 0.0347i	0.0391 + 0.0318i
0.0100 + 0.0230i	0.0363 - 0.0359i	-0.0149 - 0.0122i
0.0143 + 0.0319i	0.0105 - 0.0097i	-0.0447 - 0.0362i
Mode 4	**Mode 5**	**Mode 6**
-0.0131 - 0.0006i	0.0102 - 0.0328i	-0.0012 - 0.0011i
0.0026 - 0.0006i	-0.0142 + 0.0436i	0.0052 + 0.0052i
0.0092 + 0.0001i	-0.0010 + 0.0030i	-0.0228 - 0.0219i
0.0167 + 0.0011i	0.0113 - 0.0356i	0.0051 + 0.0049i
-0.0384 - 0.0028i	-0.0066 + 0.0221i	-0.0012 - 0.0012i
0.0371 + 0.0024i	-0.0074 + 0.0221i	0.0000 + 0.0005i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 4

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.2029	0.3201	98.7349	0.6069	0.5775	0.0528
2	12.2196	0.3974	99.0049	0.9212	0.8129	**Modal Density**
3	13.0274	0.3492	99.5874	0.8200	0.9298	1.6672
4	14.9802	0.2629	98.0435	0.7580	0.6876	**File Name**
5	14.1265	0.3263	98.5966	0.9556	0.9955	analy_green_4
6	18.2960	0.3275	69.4105	0.4302	0.2044	



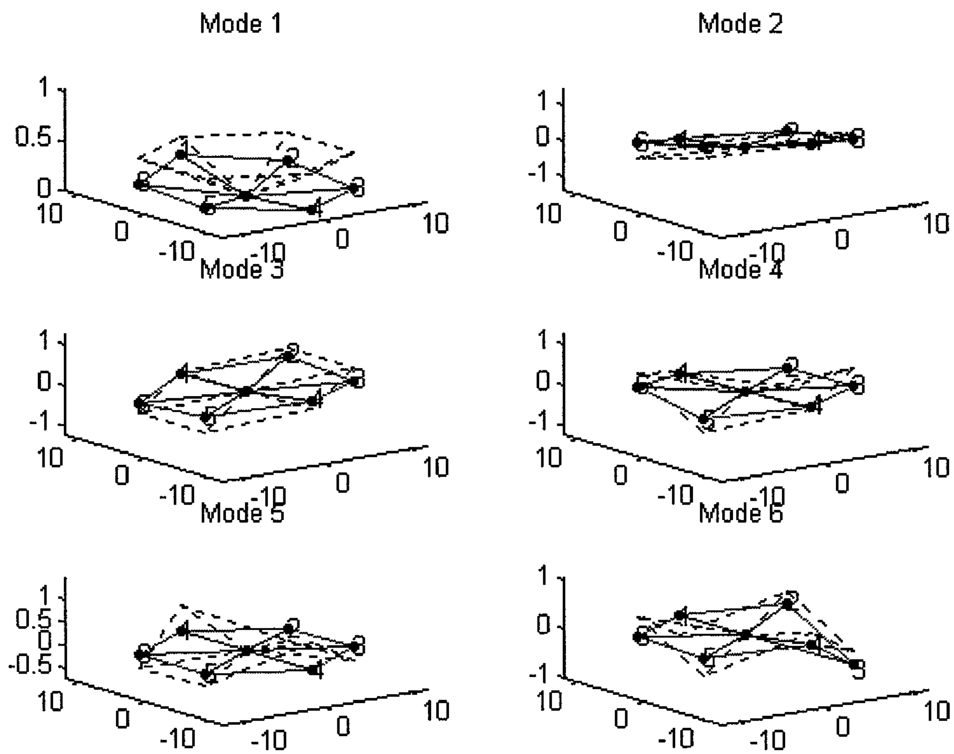
Mode 1	Mode2	Mode 3
0.0523 - 0.0014i	-0.0308 - 0.0074i	0.0001 - 0.0127i
0.0321 - 0.0008i	-0.0204 - 0.0048i	0.0004 + 0.0685i
0.0108 - 0.0005i	0.0073 + 0.0016i	0.0003 + 0.0338i
0.0180 + 0.0001i	0.0483 + 0.0109i	0.0000 + 0.0499i
0.0254 - 0.0004i	0.0496 + 0.0125i	0.0000 - 0.0189i
0.0347 - 0.0001i	0.0136 + 0.0039i	-0.0003 - 0.0571i
Mode 4	Mode 5	Mode 6
-0.0011 - 0.0129i	0.0353 - 0.0003i	-0.0009 + 0.0013i
0.0008 + 0.0023i	-0.0479 - 0.0001i	0.0044 - 0.0062i
0.0013 + 0.0091i	-0.0026 - 0.0000i	-0.0183 + 0.0262i
0.0025 + 0.0172i	0.0381 - 0.0001i	0.0040 - 0.0055i
-0.0046 - 0.0386i	-0.0232 + 0.0006i	-0.0008 + 0.0014i
0.0047 + 0.0372i	-0.0242 + 0.0000i	0.0000 - 0.0005i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 4r1

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.2173	0.2671	98.0762	0.6073	0.5803	0.0490
2	12.2036	0.3836	98.7875	0.9290	0.8124	**Modal Density**
3	13.0261	0.3474	99.6062	0.8033	0.9089	1.6362
4	14.9396	0.2569	96.6971	0.7577	0.6888	**File Name**
5	14.0862	0.3545	97.7073	0.9434	0.9812	analy_green_4r1
6	18.2129	0.3370	65.9607	0.4296	0.2034	



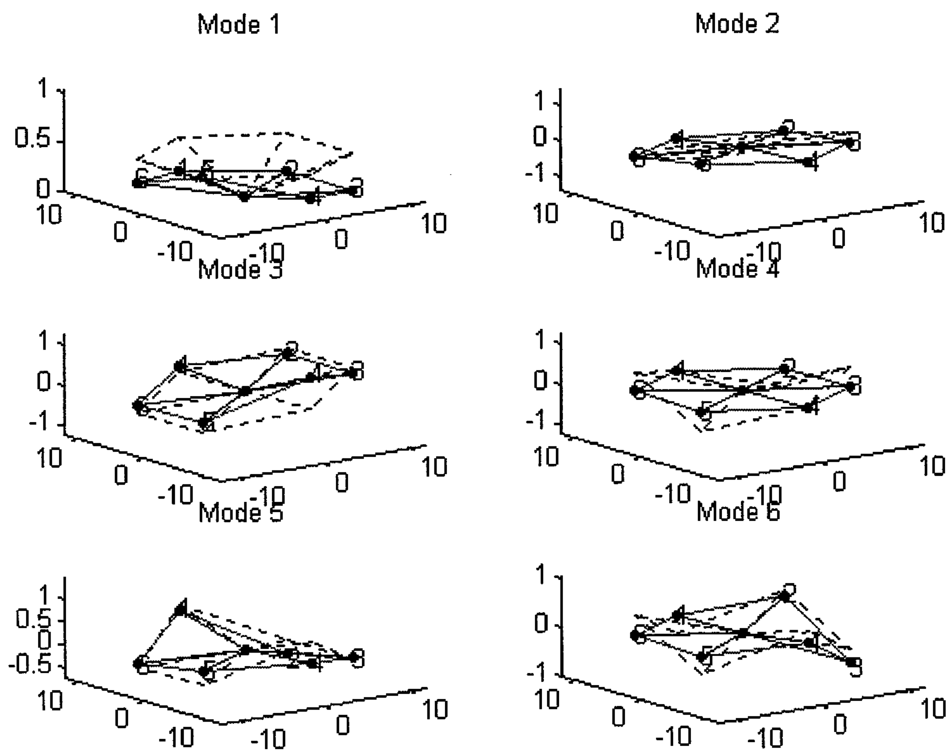
Mode 1	Mode2	Mode 3
0.0177 - 0.0488i	-0.0303 - 0.0082i	-0.0059 - 0.0111i
0.0109 - 0.0301i	-0.0198 - 0.0057i	0.0325 + 0.0598i
0.0034 - 0.0096i	0.0075 + 0.0017i	0.0161 + 0.0290i
0.0053 - 0.0164i	0.0476 + 0.0126i	0.0241 + 0.0437i
0.0081 - 0.0229i	0.0496 + 0.0143i	-0.0087 - 0.0162i
0.0119 - 0.0317i	0.0143 + 0.0047i	-0.0278 - 0.0505i
Mode 4	**Mode 5**	**Mode 6**
-0.0030 - 0.0120i	0.0005 + 0.0361i	-0.0011 + 0.0005i
0.0007 + 0.0021i	-0.0005 - 0.0491i	0.0058 - 0.0051i
0.0029 + 0.0090i	0.0002 - 0.0027i	-0.0231 + 0.0218i
0.0049 + 0.0177i	0.0005 + 0.0380i	0.0053 - 0.0053i
-0.0095 - 0.0382i	-0.0005 - 0.0221i	-0.0015 + 0.0014i
0.0093 + 0.0362i	0.0000 - 0.0255i	0.0002 - 0.0002i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 4

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.2551	0.3909	98.1609	0.6016	0.5671	0.0564
2	12.1998	0.3782	99.2409	0.9216	0.8118	**Modal Density**
3	13.0367	0.3484	99.4739	0.8059	0.9048	1.6120
4	14.8872	0.2910	98.8541	0.7538	0.6927	**File Name**
5	14.0630	0.3780	97.9864	0.9339	0.9693	analy_green_4r2
6	18.1902	0.2814	57.6383	0.4322	0.2079	



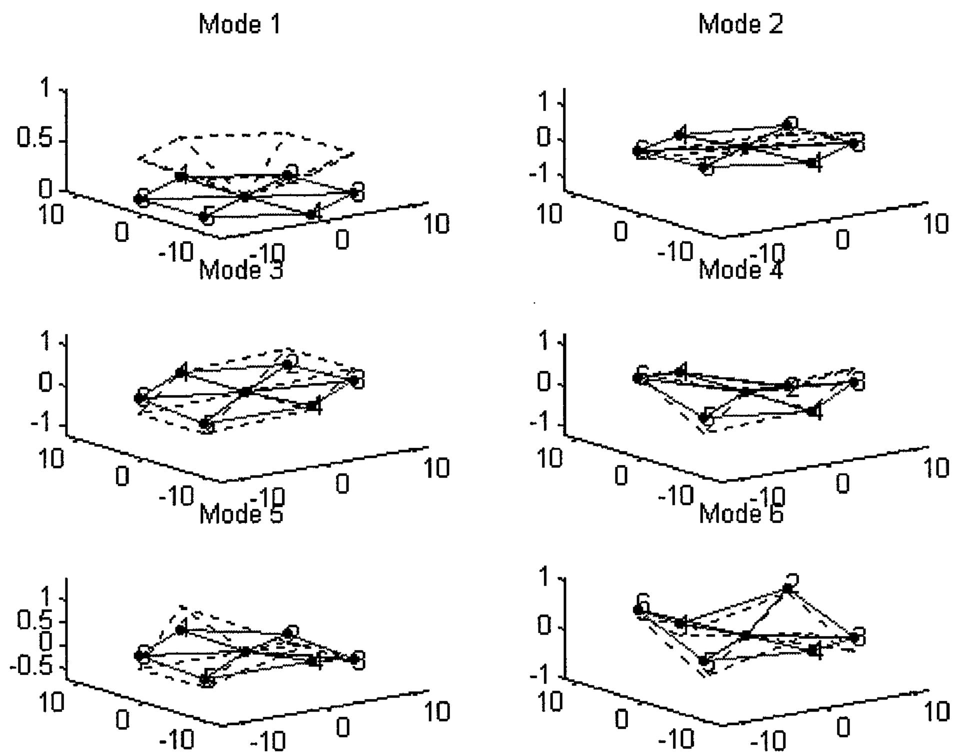
Mode 1	Mode2	Mode 3
0.0049 - 0.0084i	-0.0310 - 0.0531i	0.0134 + 0.0021i
0.0022 - 0.0042i	-0.0164 - 0.0274i	0.0343 + 0.0057i
0.0025 - 0.0052i	-0.0019 - 0.0028i	0.0341 + 0.0055i
0.0112 - 0.0210i	0.0072 + 0.0140i	0.0800 + 0.0137i
0.0273 - 0.0467i	0.0103 + 0.0158i	-0.0236 - 0.0034i
0.0119 - 0.0204i	-0.0182 - 0.0328i	-0.0290 - 0.0053i
Mode 4	**Mode 5**	**Mode 6**
-0.0017 + 0.0181i	0.0230 + 0.0180i	-0.0020 - 0.0011i
-0.0021 + 0.0374i	-0.0323 - 0.0242i	0.0091 + 0.0082i
0.0001 + 0.0027i	-0.0130 - 0.0093i	-0.0234 - 0.0191i
0.0026 - 0.0272i	0.0064 + 0.0053i	0.0054 + 0.0050i
-0.0015 + 0.0219i	0.0014 + 0.0010i	-0.0013 - 0.0002i
0.0032 - 0.0521i	-0.0131 - 0.0095i	0.0006 + 0.0002i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 5

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.7201	0.4138	97.4478	0.4890	0.3193	0.1210
2	12.4527	0.2568	98.9017	0.7754	0.6648	**Modal Density**
3	13.2177	0.3723	99.3748	0.6349	0.5948	1.9303
4	14.3139	0.4553	97.2941	0.7224	0.7870	**File Name**
5	15.3011	0.4034	96.5778	0.7932	0.6707	analy_green_5
6	18.3509	0.1511	74.8688	0.4533	0.2458	



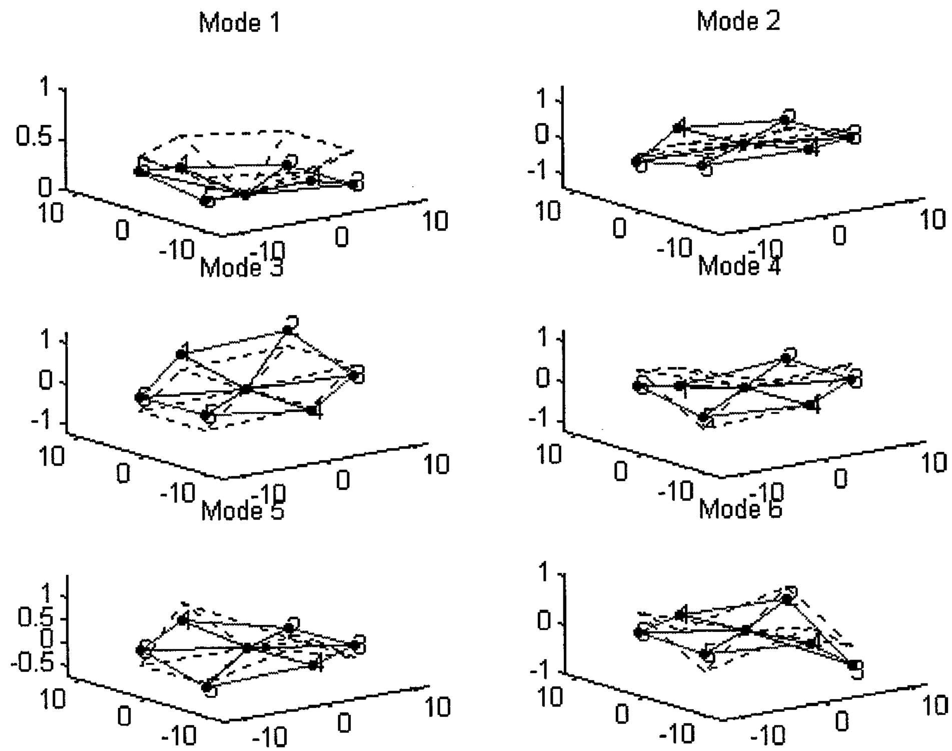
Mode 1	Mode2	Mode 3
0.0010 - 0.0135i	-0.0152 - 0.0553i	0.0004 - 0.0022i
0.0001 - 0.0097i	-0.0047 - 0.0176i	0.0058 - 0.0161i
0.0001 - 0.0190i	0.0004 + 0.0016i	0.0133 - 0.0360i
0.0016 - 0.0396i	0.0051 + 0.0187i	0.0083 - 0.0231i
0.0017 - 0.0347i	0.0019 + 0.0075i	-0.0181 + 0.0476i
0.0007 - 0.0123i	-0.0041 - 0.0145i	-0.0060 + 0.0156i
Mode 4	**Mode 5**	**Mode 6**
-0.0001 + 0.0004i	0.0067 + 0.0174i	-0.0083 + 0.0059i
-0.0239 - 0.0320i	-0.0100 - 0.0276i	0.0218 - 0.0170i
0.0069 + 0.0088i	-0.0210 - 0.0584i	-0.0047 + 0.0042i
-0.0009 - 0.0013i	0.0182 + 0.0494i	0.0018 - 0.0018i
-0.0045 - 0.0055i	-0.0097 - 0.0265i	-0.0044 + 0.0036i
0.0222 + 0.0281i	-0.0016 - 0.0046i	0.0258 - 0.0195i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2109	0.4083	98.4297	0.6158	0.5157	0.4559
2	11.0480	0.4364	95.6257	0.6590	0.4127	**Modal Density**
3	11.6362	0.2702	99.0228	0.7114	0.7312	1.3845
4	15.3875	0.2465	89.1931	0.6918	0.5550	**File Name**
5	12.8972	0.3009	98.4423	0.8655	0.7793	analy_green_6
6	15.7677	0.2686	94.7469	0.5639	0.3918	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 6

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



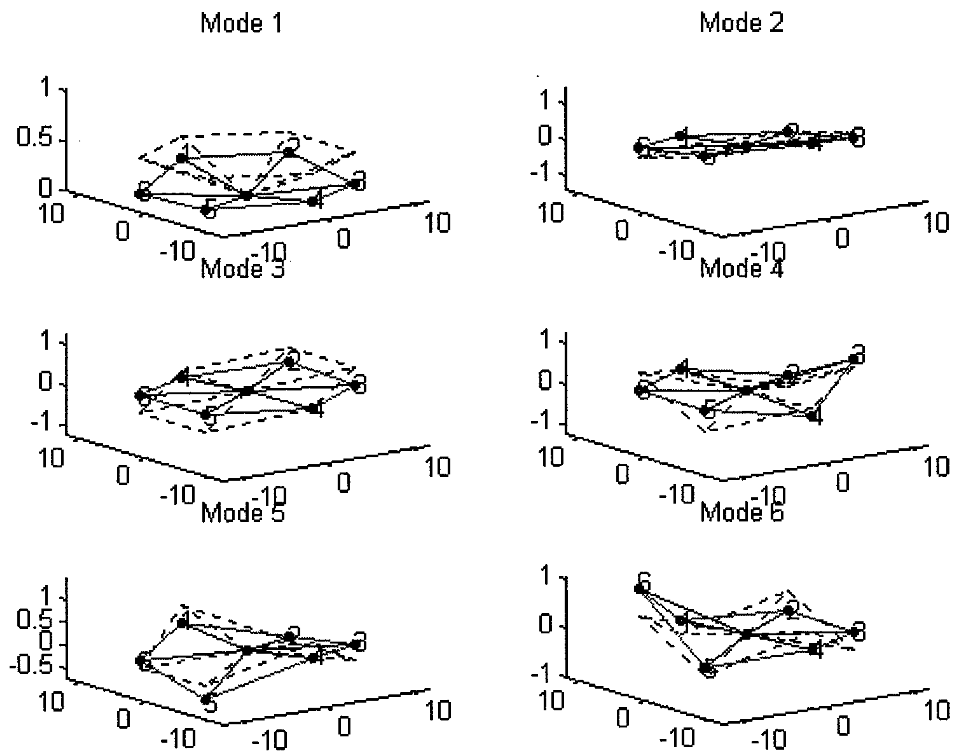
Mode 1	Mode2	Mode 3
0.0051 + 0.0095i	-0.0074 + 0.0104i	0.0329 - 0.0071i
0.0040 + 0.0066i	-0.0011 + 0.0014i	0.0798 - 0.0175i
0.0048 + 0.0080i	0.0041 - 0.0059i	0.0200 - 0.0046i
0.0198 + 0.0354i	0.0207 - 0.0303i	-0.0056 + 0.0014i
0.0100 + 0.0179i	-0.0018 + 0.0017i	-0.0083 + 0.0020i
0.0164 + 0.0304i	-0.0269 + 0.0361i	-0.0107 + 0.0024i
Mode 4	**Mode 5**	**Mode 6**
-0.0213 - 0.0322i	0.0085 - 0.0150i	-0.0028 + 0.0015i
0.0059 + 0.0102i	-0.0028 + 0.0068i	0.0061 - 0.0040i
0.0046 + 0.0072i	-0.0001 - 0.0001i	-0.0272 + 0.0183i
0.0003 + 0.0006i	0.0028 - 0.0067i	0.0033 - 0.0019i
-0.0090 - 0.0152i	-0.0185 + 0.0444i	-0.0013 + 0.0006i
0.0041 + 0.0068i	0.0016 - 0.0047i	0.0002 - 0.0005i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 7

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1243	0.4200	98.0284	0.5970	0.4768	0.1811
2	10.5822	0.3043	96.6521	0.7699	0.5440	**Modal Density**
3	12.6726	0.3632	97.3736	0.5626	0.3880	2.2227
4	15.7855	0.3652	91.1064	0.5904	0.4598	**File Name**
5	15.4419	0.2360	84.8701	0.6286	0.3452	analy_green_7
6	18.1751	0.3853	74.5391	0.4233	0.1920	



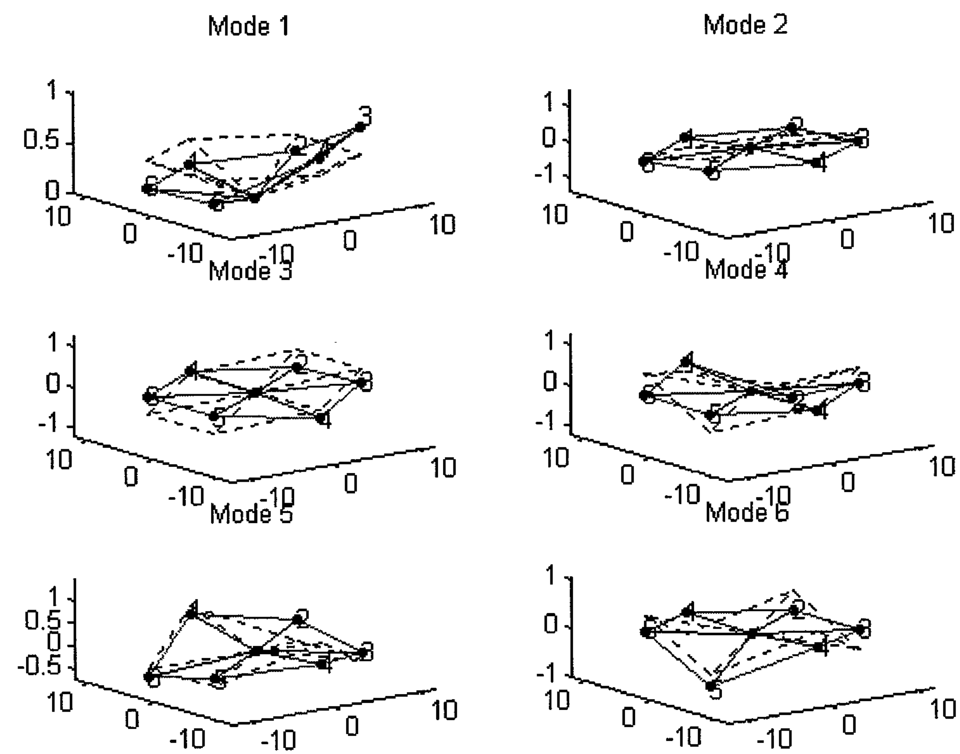
Mode 1	Mode2	Mode 3
0.0138 - 0.0357i	-0.0208 - 0.0171i	-0.0136 + 0.0589i
0.0162 - 0.0426i	-0.0193 - 0.0156i	0.0126 - 0.0568i
0.0069 - 0.0188i	0.0065 + 0.0049i	0.0055 - 0.0257i
0.0106 - 0.0285i	0.0388 + 0.0308i	0.0013 - 0.0051i
0.0061 - 0.0174i	0.0207 + 0.0172i	-0.0075 + 0.0329i
0.0046 - 0.0121i	0.0000 + 0.0001i	-0.0063 + 0.0280i
Mode 4	**Mode 5**	**Mode 6**
0.0012 - 0.0006i	0.0173 + 0.0184i	-0.0050 - 0.0004i
-0.0080 + 0.0077i	-0.0160 - 0.0163i	0.0007 - 0.0002i
0.0299 - 0.0282i	0.0069 + 0.0072i	-0.0011 - 0.0001i
-0.0078 + 0.0080i	0.0248 + 0.0259i	0.0015 + 0.0000i
0.0020 - 0.0016i	-0.0521 - 0.0549i	-0.0090 - 0.0006i
0.0028 - 0.0023i	-0.0133 - 0.0137i	0.0350 + 0.0051i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	11.0060	0.3557	98.4244	0.6563	0.6316	0.0185
2	11.5884	0.3755	89.3303	0.7889	0.7044	**Modal Density**
3	12.7737	0.2901	98.5114	0.8151	0.8664	1.6554
4	15.8962	0.3519	91.4555	0.5385	0.3326	**File Name**
5	13.7305	0.3405	98.9355	0.7089	0.5285	analy_green_8
6	17.9347	0.1566	78.5667	0.4259	0.1966	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 8

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



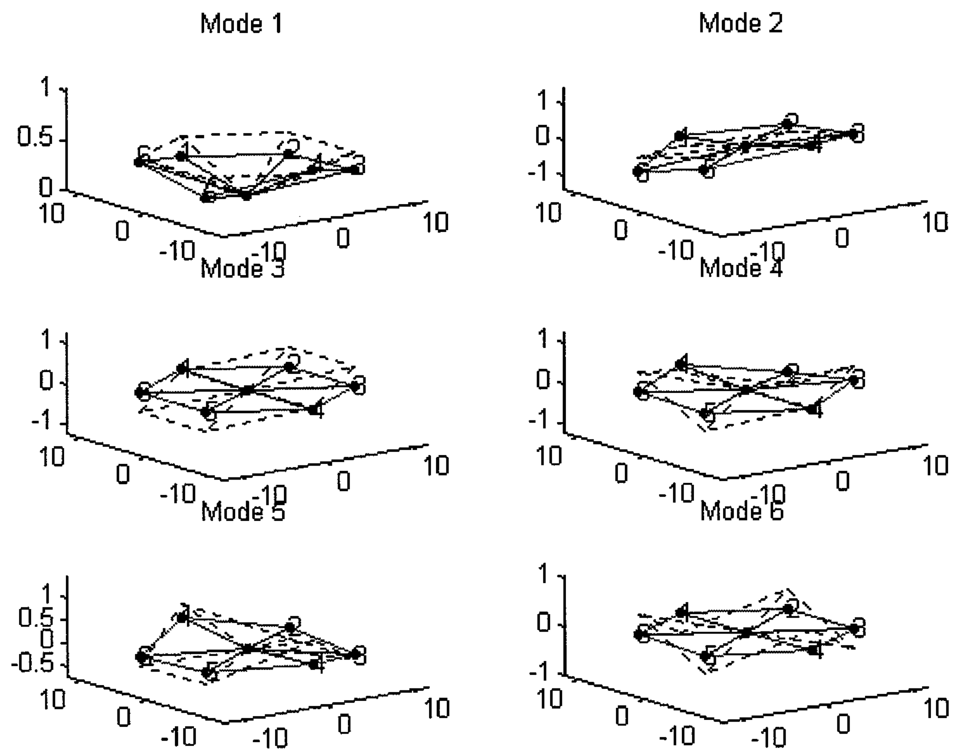
Mode 1	Mode2	Mode 3
0.0083 - 0.0005i	-0.0230 + 0.0432i	0.0029 - 0.0095i
0.0138 - 0.0025i	-0.0060 + 0.0109i	0.0052 - 0.0185i
0.0382 - 0.0077i	0.0049 - 0.0091i	0.0090 - 0.0331i
0.0338 - 0.0070i	0.0047 - 0.0075i	-0.0147 + 0.0541i
0.0091 - 0.0018i	-0.0046 + 0.0091i	-0.0050 + 0.0185i
0.0074 - 0.0007i	-0.0225 + 0.0424i	-0.0035 + 0.0120i
Mode 4	**Mode 5**	**Mode 6**
0.0104 - 0.0091i	0.0398 - 0.0453i	0.0004 - 0.0011i
-0.0360 + 0.0308i	0.0176 - 0.0199i	0.0005 + 0.0004i
0.0050 - 0.0044i	-0.0102 + 0.0117i	-0.0001 - 0.0002i
-0.0010 + 0.0011i	0.0120 - 0.0139i	0.0033 + 0.0033i
-0.0025 + 0.0025i	-0.0118 + 0.0131i	-0.0238 - 0.0278i
-0.0028 + 0.0026i	-0.0458 + 0.0514i	0.0038 + 0.0049i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 9

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.0441	0.3939	97.7638	0.5850	0.4284	0.0687
2	11.2395	0.5610	98.2855	0.8462	0.5958	**Modal Density**
3	11.7695	0.2851	98.6723	0.6504	0.6105	2.1566
4	15.5732	0.1638	82.5621	0.5288	0.3103	**File Name**
5	12.9980	0.3582	99.2049	0.8380	0.6822	analy_green_9
6	17.8451	0.1869	69.1332	0.4175	0.1821	



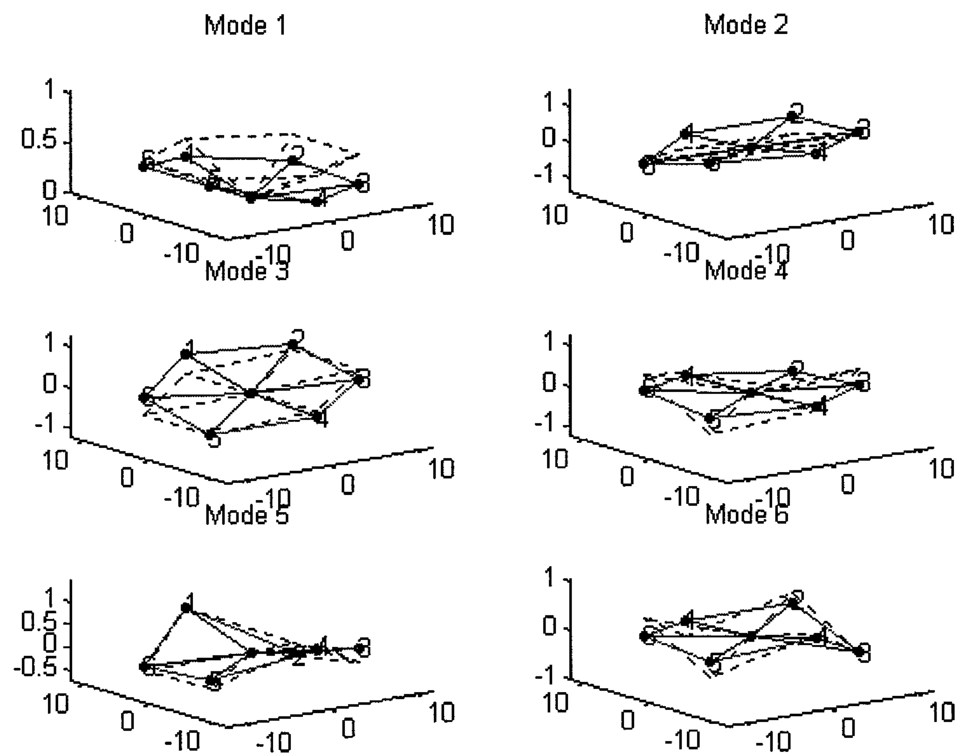
Mode 1	Mode2	Mode 3
0.0114 - 0.0106i	-0.0155 - 0.0072i	0.0013 - 0.0251i
0.0107 - 0.0108i	-0.0029 - 0.0013i	0.0018 - 0.0508i
0.0124 - 0.0117i	0.0095 + 0.0043i	0.0009 - 0.0224i
0.0243 - 0.0227i	0.0248 + 0.0115i	-0.0009 + 0.0162i
0.0114 - 0.0113i	-0.0021 - 0.0007i	-0.0007 + 0.0143i
0.0199 - 0.0182i	-0.0308 - 0.0138i	-0.0009 + 0.0203i
Mode 4	Mode 5	Mode 6
0.0100 - 0.0401i	0.0192 - 0.0523i	0.0001 - 0.0048i
-0.0138 + 0.0585i	-0.0022 + 0.0068i	-0.0004 + 0.0066i
0.0116 - 0.0466i	-0.0156 + 0.0436i	0.0004 - 0.0150i
-0.0019 + 0.0085i	0.0067 - 0.0185i	-0.0033 + 0.0830i
-0.0051 + 0.0183i	-0.0005 + 0.0009i	0.0004 - 0.0158i
-0.0010 + 0.0056i	-0.0073 + 0.0199i	0.0038 + 0.0049i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.3115	0.4926	97.7041	0.6559	0.6743	0.0882
2	9.7982	0.2914	92.7704	0.8214	0.6797	**Modal Density**
3	10.5756	0.3726	99.0479	0.6670	0.6946	1.2184
4	12.7545	0.2500	99.2090	0.7488	0.7652	**File Name**
5	11.9376	0.2975	97.3871	0.8113	0.6450	analy_green_10
6	13.8689	0.3258	96.8712	0.4251	0.1955	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 10

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40



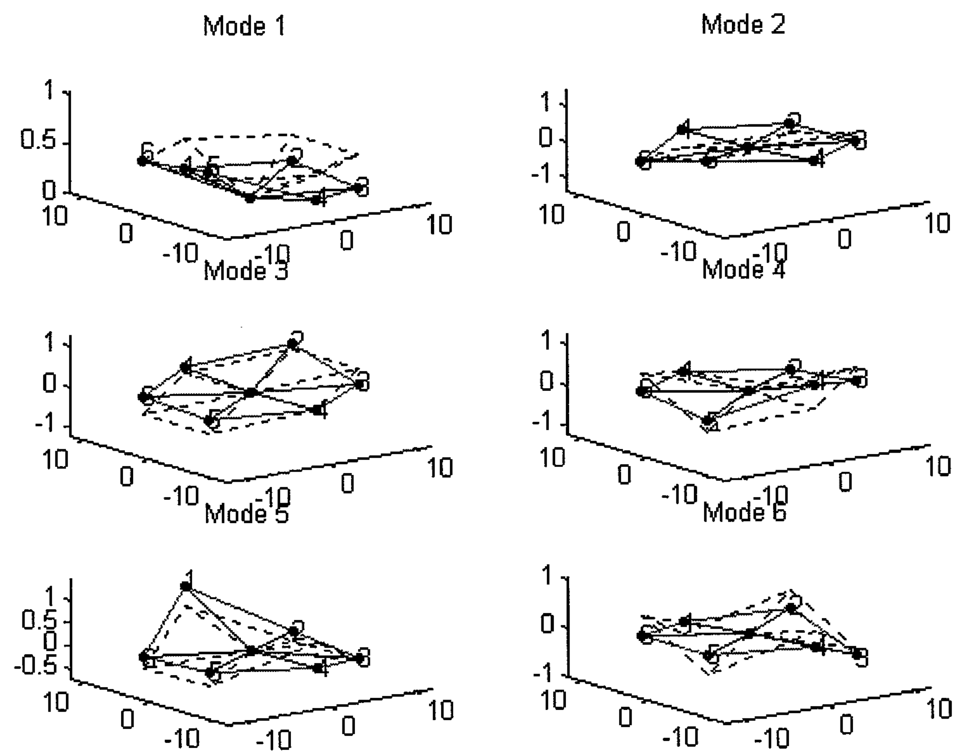
Mode 1	Mode2	Mode 3
0.0121 + 0.0162i	-0.0115 + 0.0110i	0.0323 + 0.0047i
0.0091 + 0.0116i	0.0154 - 0.0146i	0.0435 + 0.0063i
0.0058 + 0.0072i	0.0204 - 0.0197i	0.0146 + 0.0023i
0.0094 + 0.0122i	0.0231 - 0.0226i	-0.0098 - 0.0018i
0.0199 + 0.0261i	0.0117 - 0.0111i	-0.0341 - 0.0050i
0.0199 + 0.0261i	-0.0239 + 0.0233i	-0.0031 - 0.0002i
Mode 4	**Mode 5**	**Mode 6**
-0.0060 - 0.0254i	0.0435 + 0.0204i	-0.0075 - 0.0109i
-0.0037 - 0.0146i	-0.0373 - 0.0170i	0.0165 + 0.0241i
0.0087 + 0.0342i	0.0000 + 0.0004i	-0.0327 - 0.0486i
0.0080 + 0.0296i	0.0370 + 0.0169i	0.0283 + 0.0417i
-0.0094 - 0.0361i	-0.0094 - 0.0042i	-0.0083 - 0.0121i
0.0090 + 0.0362i	-0.0162 - 0.0073i	0.0041 + 0.0059i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 11

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.4917	0.5439	98.2626	0.6931	0.6185	0.1589
2	10.8492	0.3336	98.7097	1.0844	1.1648	**Modal Density**
3	10.4621	0.3217	96.0560	0.7637	0.8032	1.0911
4	12.1922	0.2222	98.9996	1.0268	1.2660	**File Name**
5	12.5041	0.3161	86.7322	0.9352	0.8356	analy_green_11
6	13.7257	0.3105	98.1489	0.5940	0.4622	



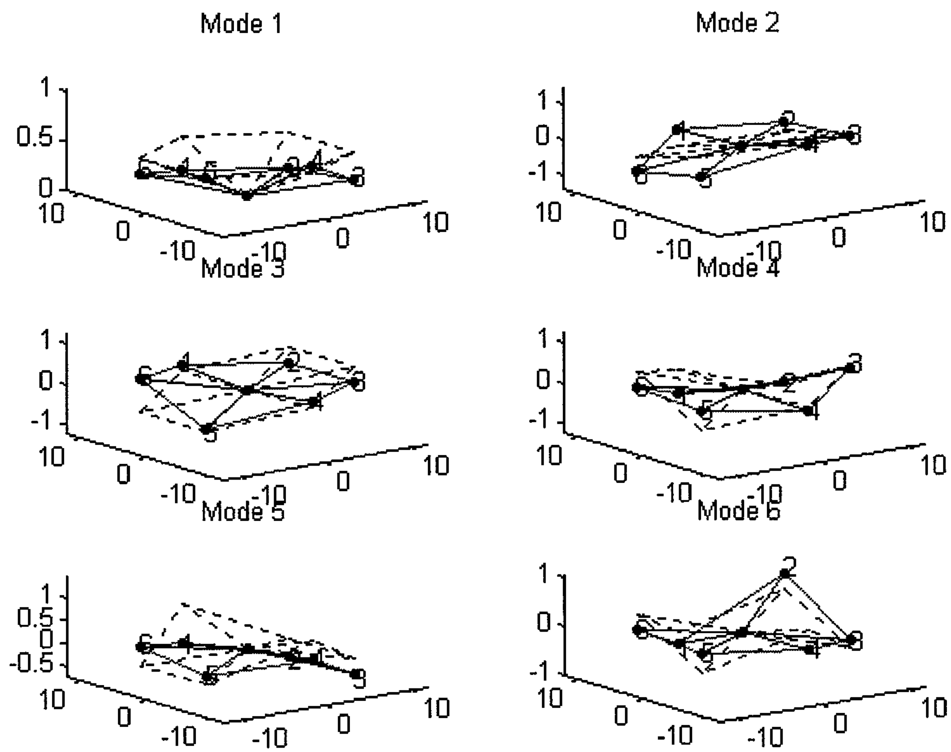
Mode 1	Mode2	Mode 3
0.0058 - 0.0062i	-0.0037 + 0.0085i	0.0061 - 0.0065i
0.0080 - 0.0073i	0.0014 - 0.0032i	0.0312 - 0.0365i
0.0034 - 0.0030i	0.0023 - 0.0053i	0.0055 - 0.0067i
0.0096 - 0.0098i	0.0099 - 0.0219i	0.0003 + 0.0000i
0.0263 - 0.0271i	0.0149 - 0.0318i	-0.0065 + 0.0076i
0.0230 - 0.0250i	-0.0192 + 0.0406i	-0.0023 + 0.0042i
Mode 4	**Mode 5**	**Mode 6**
0.0004 - 0.0003i	0.0388 - 0.0020i	-0.0065 - 0.0103i
-0.0035 + 0.0039i	-0.0021 + 0.0001i	0.0020 + 0.0032i
0.0096 - 0.0105i	-0.0087 - 0.0001i	-0.0172 - 0.0259i
0.0403 - 0.0440i	0.0014 + 0.0002i	0.0030 + 0.0045i
-0.0141 + 0.0162i	0.0000 - 0.0003i	-0.0005 - 0.0004i
0.0047 - 0.0057i	-0.0028 + 0.0003i	0.0005 + 0.0007i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 12

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.1778	0.3882	97.1420	0.5901	0.4317	0.0258
2	10.6489	0.4146	96.2839	0.8088	0.6604	**Modal Density**
3	9.8005	0.2868	85.5511	0.5292	0.3124	2.8805
4	12.3160	0.3091	93.8257	0.5498	0.3582	**File Name**
5	17.6321	0.2345	77.5500	0.5945	0.2804	analy_green_12
6	18.0793	0.3165	82.2652	0.4470	0.2339	



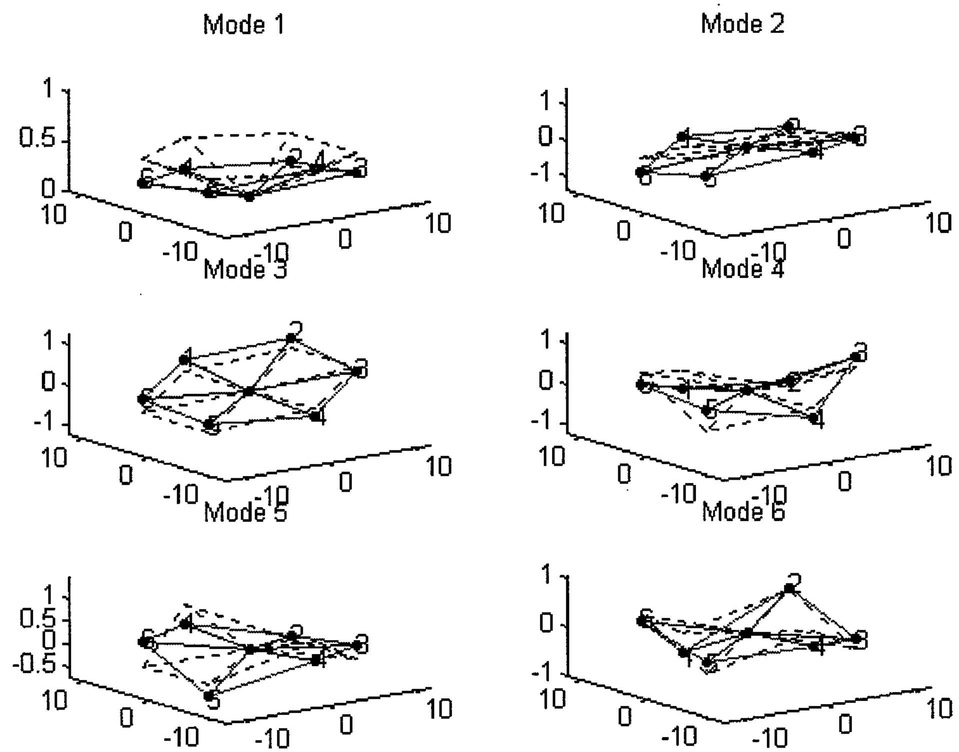
Mode 1	Mode2	Mode 3
0.0038 - 0.0033i	-0.0090 + 0.0043i	0.0096 - 0.0121i
0.0027 - 0.0029i	0.0003 - 0.0004i	0.0059 - 0.0081i
0.0069 - 0.0072i	0.0085 - 0.0043i	0.0067 - 0.0096i
0.0265 - 0.0265i	0.0286 - 0.0130i	0.0101 - 0.0129i
0.0225 - 0.0220i	-0.0173 + 0.0079i	-0.0319 + 0.0396i
0.0143 - 0.0135i	-0.0378 + 0.0170i	0.0235 - 0.0290i
Mode 4	Mode 5	Mode 6
-0.0407 - 0.0256i	-0.0314 + 0.0060i	-0.0256 + 0.0022i
-0.0250 - 0.0160i	-0.0705 + 0.0147i	0.0294 - 0.0036i
0.0301 + 0.0172i	-0.0689 + 0.0143i	-0.0100 + 0.0013i
-0.0049 - 0.0026i	0.0191 - 0.0041i	0.0011 - 0.0007i
-0.0006 - 0.0005i	-0.0107 + 0.0026i	-0.0003 - 0.0002i
0.0071 + 0.0044i	0.0133 - 0.0030i	0.0031 - 0.0008i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 13

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.2727	0.3041	97.3695	0.5888	0.4570	0.0856
2	10.2899	0.3858	73.2411	0.7948	0.6503	**Modal Density**
3	11.5896	0.3084	98.6160	0.6761	0.6356	2.1550
4	14.6484	0.3220	93.3436	0.6971	0.6671	**File Name**
5	13.0677	0.3685	99.0422	0.8729	0.6668	analy_green_13
6	16.4705	0.3481	82.7059	0.5596	0.3734	



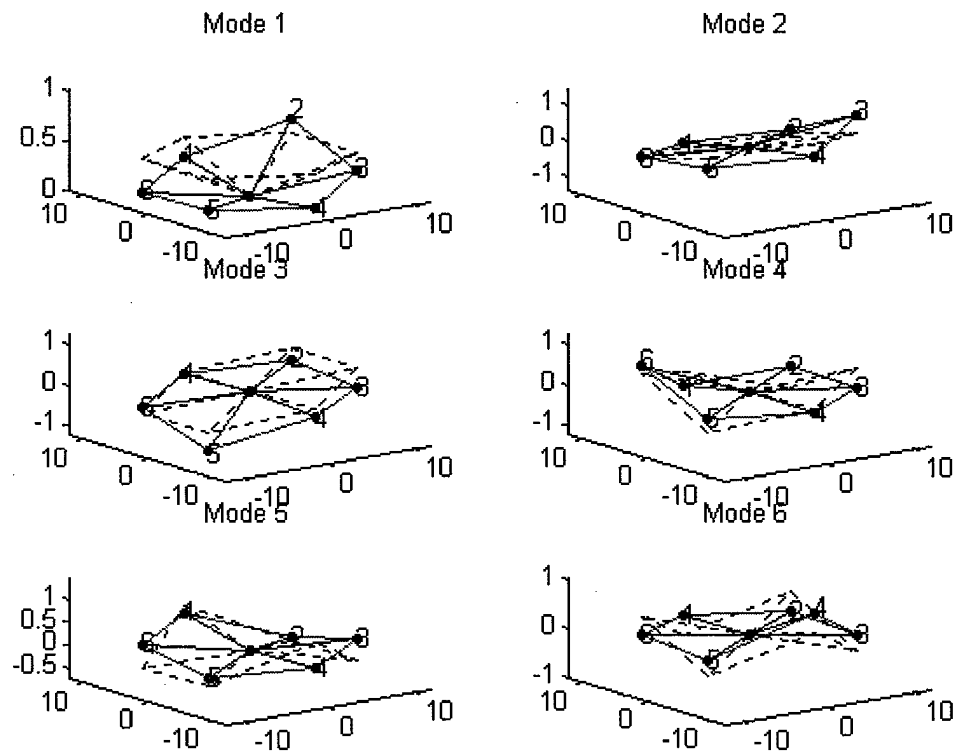
Mode 1	Mode2	Mode 3
0.0039 - 0.0057i	-0.0197 - 0.0095i	0.0200 - 0.0057i
0.0061 - 0.0082i	-0.0075 - 0.0033i	0.0544 - 0.0153i
0.0102 - 0.0114i	0.0076 + 0.0039i	0.0288 - 0.0075i
0.0224 - 0.0261i	0.0225 + 0.0105i	-0.0122 + 0.0032i
0.0125 - 0.0166i	-0.0155 - 0.0077i	-0.0232 + 0.0060i
0.0085 - 0.0110i	-0.0429 - 0.0212i	-0.0092 + 0.0026i
Mode 4	Mode 5	Mode 6
-0.0432 + 0.0121i	0.0124 + 0.0147i	-0.0554 + 0.0086i
-0.0347 + 0.0100i	-0.0174 - 0.0208i	0.0302 - 0.0051i
0.0710 - 0.0203i	0.0007 + 0.0016i	-0.0154 + 0.0021i
-0.0243 + 0.0071i	0.0163 + 0.0188i	0.0052 - 0.0009i
0.0059 - 0.0017i	-0.0528 - 0.0639i	-0.0110 + 0.0017i
0.0189 - 0.0053i	0.0240 + 0.0288i	0.0184 - 0.0031i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.8573	0.3805	95.2704	0.5560	0.4744	0.1096
2	10.9079	0.2958	98.2040	0.7455	0.6128	**Modal Density**
3	11.3560	0.3330	98.5557	0.6467	0.6181	1.1357
4	13.2187	0.3372	99.3013	0.6712	0.6702	**File Name**
5	13.0002	0.3522	98.8038	0.6966	0.4978	analy_green_14
6	14.4055	0.2985	97.9473	0.5057	0.3538	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 14

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



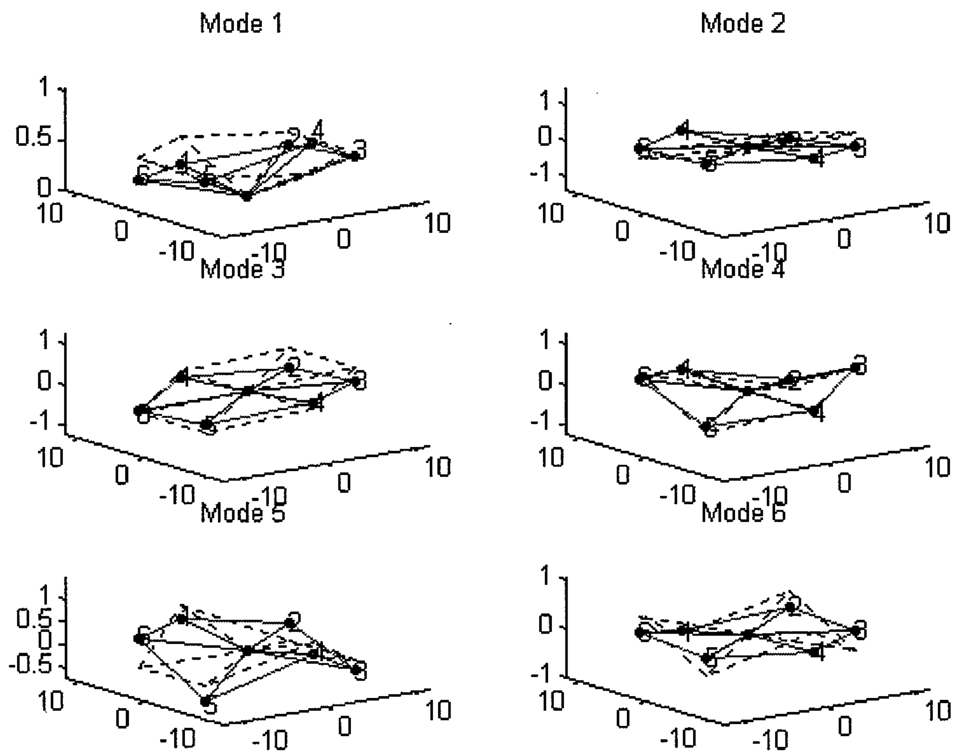
Mode 1	Mode2	Mode 3
0.0106 + 0.0128i	-0.0331 - 0.0098i	-0.0022 + 0.0002i
0.0291 + 0.0335i	-0.0113 - 0.0030i	0.0111 + 0.0005i
0.0117 + 0.0133i	0.0544 + 0.0144i	-0.0002 + 0.0000i
0.0036 + 0.0045i	0.0169 + 0.0047i	-0.0112 - 0.0006i
0.0046 + 0.0060i	0.0009 + 0.0004i	-0.0501 - 0.0022i
0.0042 + 0.0053i	-0.0169 - 0.0051i	-0.0172 - 0.0011i
Mode 4	**Mode 5**	**Mode 6**
-0.0259 - 0.0191i	0.0272 - 0.0464i	0.0002 + 0.0002i
0.0039 + 0.0031i	-0.0124 + 0.0215i	0.0006 + 0.0004i
0.0000 - 0.0002i	0.0124 - 0.0223i	-0.0033 - 0.0026i
-0.0045 - 0.0036i	0.0021 - 0.0034i	0.0296 + 0.0222i
-0.0101 - 0.0076i	-0.0077 + 0.0139i	-0.0029 - 0.0020i
0.0535 + 0.0409i	0.0147 - 0.0254i	0.0012 + 0.0004i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.4626	0.4006	93.3796	0.4774	0.2978	0.0722
2	11.6257	0.2870	95.1540	0.7337	0.5611	**Modal Density**
3	10.2945	0.4042	86.9366	0.5522	0.3649	2.4448
4	14.2053	0.3219	83.0701	0.5649	0.3867	**File Name**
5	12.3145	0.3563	98.4745	0.7810	0.7017	analy_green_15
6	17.5628	0.2707	69.5916	0.4130	0.1745	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 15

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



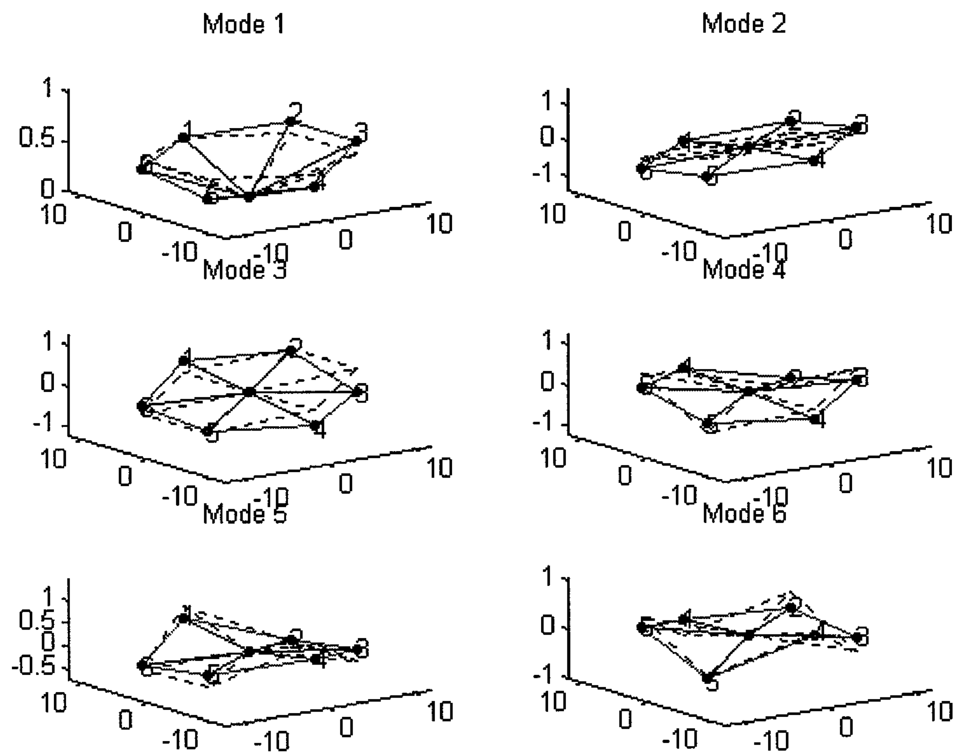
Mode 1	Mode2	Mode 3
0.0056 - 0.0014i	-0.0082 - 0.0122i	-0.0101 + 0.0138i
0.0141 - 0.0041i	-0.0293 - 0.0435i	0.0005 + 0.0009i
0.0171 - 0.0033i	-0.0085 - 0.0129i	0.0092 - 0.0122i
0.0344 - 0.0065i	0.0115 + 0.0178i	0.0106 - 0.0156i
0.0177 - 0.0028i	0.0077 + 0.0113i	-0.0222 + 0.0287i
0.0094 - 0.0019i	0.0005 - 0.0001i	-0.0309 + 0.0414i
Mode 4	**Mode 5**	**Mode 6**
0.0049 - 0.0041i	0.0270 + 0.0094i	-0.0161 - 0.0412i
-0.0277 + 0.0267i	0.0110 + 0.0042i	0.0034 + 0.0088i
0.0469 - 0.0447i	-0.0463 - 0.0163i	-0.0007 - 0.0023i
-0.0057 + 0.0062i	0.0306 + 0.0101i	0.0001 + 0.0012i
-0.0336 + 0.0308i	-0.0594 - 0.0196i	-0.0014 - 0.0036i
0.0360 - 0.0329i	0.0327 + 0.0107i	0.0040 + 0.0127i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 16

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.8904	0.3521	94.7667	0.5461	0.4570	0.0623
2	10.9305	0.2122	90.5458	0.6824	0.4670	**Modal Density**
3	11.4376	0.2953	95.4875	0.6753	0.6493	1.5168
4	13.1389	0.2652	98.9964	0.7808	0.8804	**File Name**
5	13.3135	0.3744	99.2106	0.8998	0.9296	analy_orange_16
6	15.6907	0.2966	91.7898	0.4373	0.2172	



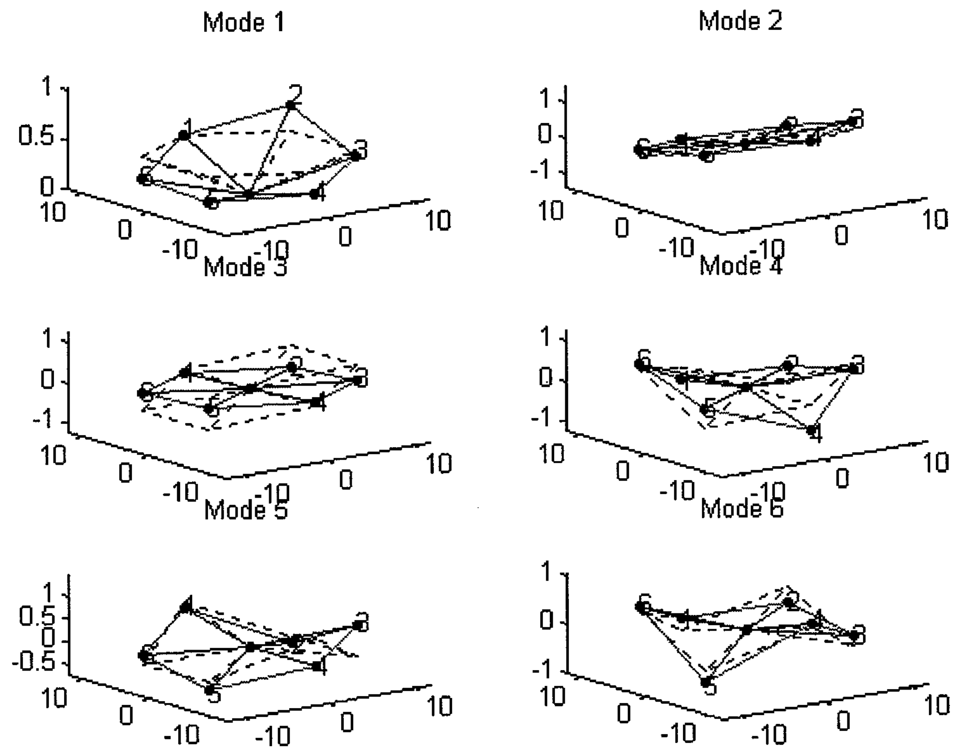
Mode 1	Mode2	Mode 3
0.0272 - 0.0052i	-0.0308 + 0.0184i	0.0262 - 0.0162i
0.0366 - 0.0070i	0.0047 - 0.0026i	0.0389 - 0.0240i
0.0363 - 0.0071i	0.0316 - 0.0186i	-0.0102 + 0.0066i
0.0207 - 0.0040i	0.0110 - 0.0065i	-0.0348 + 0.0213i
0.0146 - 0.0033i	-0.0153 + 0.0085i	-0.0390 + 0.0242i
0.0207 - 0.0043i	-0.0400 + 0.0231i	-0.0241 + 0.0146i
Mode 4	Mode 5	Mode 6
0.0076 + 0.0151i	0.0289 + 0.0510i	-0.0046 - 0.0055i
-0.0266 - 0.0463i	-0.0197 - 0.0350i	0.0039 + 0.0048i
0.0214 + 0.0357i	-0.0014 - 0.0019i	-0.0058 - 0.0070i
-0.0215 - 0.0353i	0.0218 + 0.0381i	0.0212 + 0.0261i
-0.0262 - 0.0450i	-0.0019 - 0.0031i	-0.0245 - 0.0296i
0.0175 + 0.0280i	-0.0208 - 0.0370i	0.0102 + 0.0128i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 17

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.4643	0.3624	98.7755	0.7459	0.7423	0.1343
2	11.3467	0.3841	98.3060	0.9072	0.8520	**Modal Density**
3	11.9313	0.3666	99.0729	0.9592	1.1446	1.0055
4	13.3675	0.2951	99.1894	0.9541	1.1879	**File Name**
5	13.5617	0.2746	97.7119	0.9239	0.9054	analy_green_17
6	14.8191	0.2804	96.1056	0.5868	0.4370	



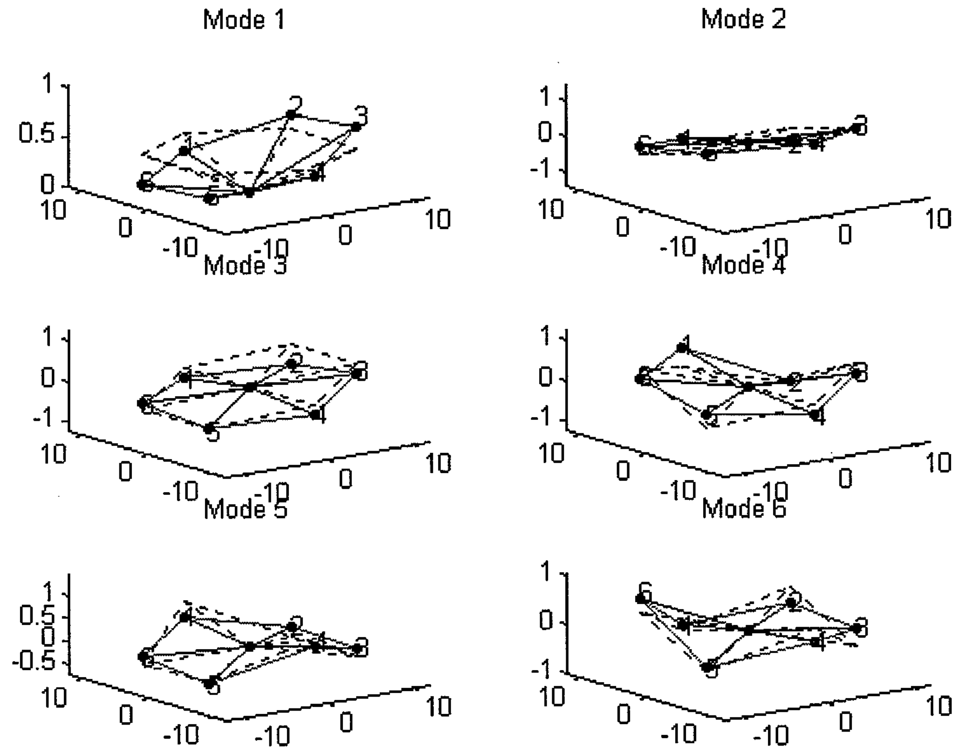
Mode 1	Mode2	Mode 3
0.0255 - 0.0119i	-0.0403 + 0.0072i	-0.0100 + 0.0358i
0.0419 - 0.0191i	-0.0145 - 0.0052i	-0.0026 - 0.0295i
0.0223 - 0.0108i	0.0415 - 0.0039i	0.0094 - 0.0187i
0.0124 - 0.0055i	0.0478 + 0.0027i	0.0102 + 0.0148i
0.0092 - 0.0046i	0.0251 + 0.0082i	0.0043 + 0.0441i
0.0119 - 0.0055i	-0.0095 + 0.0095i	-0.0033 + 0.0502i
Mode 4	**Mode 5**	**Mode 6**
-0.0233 + 0.0007i	0.0433 - 0.0290i	-0.0095 + 0.0021i
-0.0023 + 0.0002i	-0.0384 + 0.0257i	0.0040 - 0.0009i
0.0279 - 0.0014i	0.0392 - 0.0261i	-0.0096 + 0.0018i
-0.0484 + 0.0021i	0.0013 - 0.0013i	0.0243 - 0.0039i
-0.0008 + 0.0004i	-0.0461 + 0.0303i	-0.0322 + 0.0050i
0.0491 - 0.0020i	-0.0091 + 0.0058i	0.0252 - 0.0037i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 18

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.3588	0.3919	98.0480	0.5601	0.4758	0.2495
2	11.8594	0.3159	98.7340	0.9956	0.9975	**Modal Density**
3	11.8954	0.3009	99.0149	0.8607	1.0654	1.1386
4	14.1138	0.3794	94.1487	0.7942	0.7574	**File Name**
5	13.3631	0.2861	98.5575	1.0589	1.0019	analy_green_18
6	15.1486	0.3171	93.5141	0.6295	0.5488	



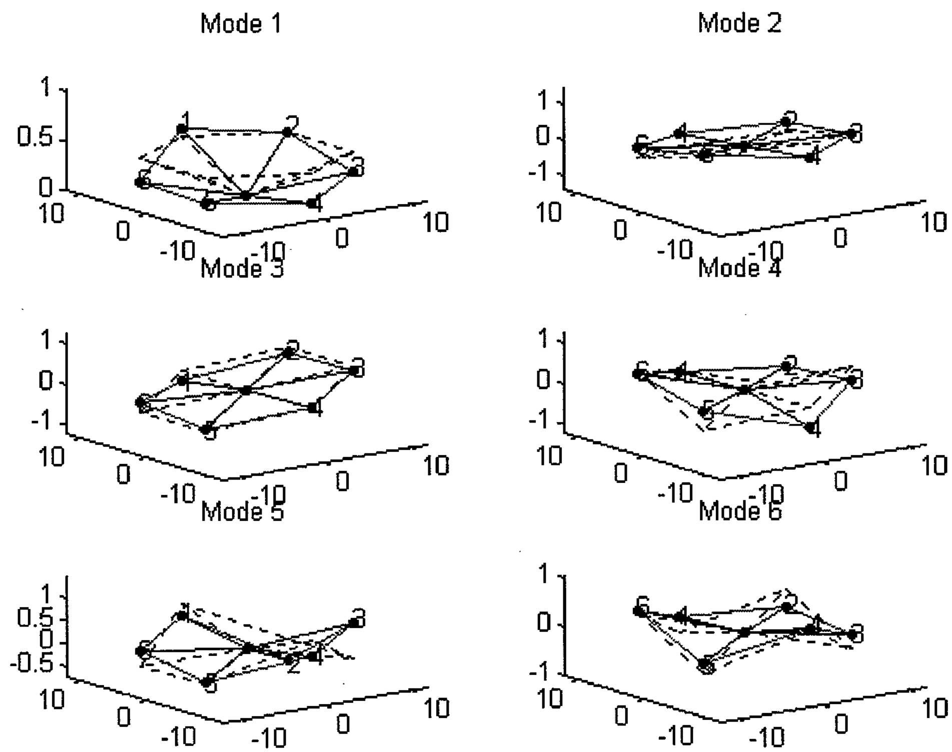
Mode 1	Mode2	Mode 3
0.0158 + 0.0046i	-0.0404 - 0.0073i	-0.0220 - 0.0188i
0.0378 + 0.0106i	-0.0541 - 0.0094i	0.0017 + 0.0019i
0.0435 + 0.0122i	0.0251 + 0.0045i	0.0194 + 0.0163i
0.0240 + 0.0065i	0.0414 + 0.0074i	-0.0173 - 0.0160i
0.0119 + 0.0032i	0.0257 + 0.0044i	-0.0413 - 0.0367i
0.0077 + 0.0016i	-0.0054 - 0.0012i	-0.0278 - 0.0242i
Mode 4	**Mode 5**	**Mode 6**
0.0410 + 0.0352i	0.0141 - 0.0191i	-0.0118 - 0.0078i
-0.0372 - 0.0308i	-0.0026 + 0.0037i	0.0029 + 0.0023i
0.0198 + 0.0162i	-0.0070 + 0.0098i	-0.0014 - 0.0008i
-0.0205 - 0.0170i	0.0282 - 0.0386i	0.0056 + 0.0042i
-0.0142 - 0.0124i	-0.0204 + 0.0283i	-0.0135 - 0.0094i
0.0241 + 0.0202i	-0.0098 + 0.0137i	0.0298 + 0.0213i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 19

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.5912	0.3583	98.6996	0.6184	0.5205	0.2363
2	12.0770	0.3445	99.2490	0.9303	0.9606	**Modal Density**
3	12.3818	0.3302	98.4597	0.7267	0.8266	1.3276
4	13.8681	0.2741	99.5215	0.8255	0.9901	**File Name**
5	14.4474	0.2629	99.2094	0.8112	0.7150	analy_green_19
6	16.1584	0.3850	94.2712	0.4827	0.3061	



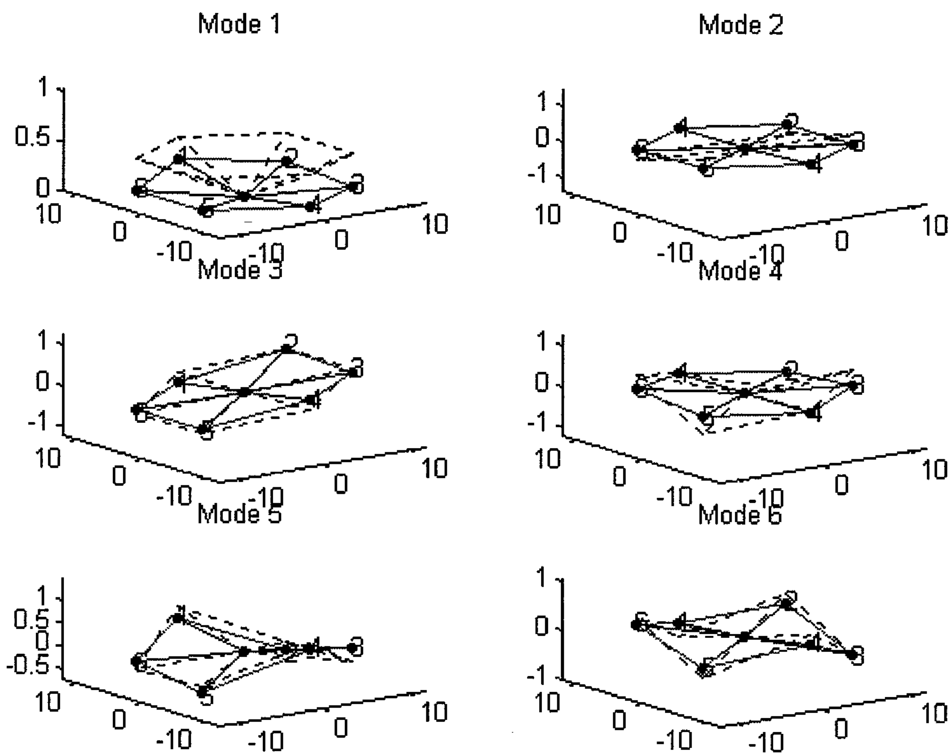
Mode 1	Mode2	Mode 3
0.0322 - 0.0322i	-0.0176 + 0.0291i	-0.0203 - 0.0174i
0.0274 - 0.0274i	0.0013 + 0.0005i	0.0270 + 0.0241i
0.0142 - 0.0150i	0.0163 - 0.0271i	0.0306 + 0.0261i
0.0075 - 0.0075i	0.0158 - 0.0284i	0.0008 - 0.0000i
0.0098 - 0.0101i	0.0257 - 0.0484i	-0.0342 - 0.0323i
0.0112 - 0.0113i	0.0027 - 0.0068i	-0.0192 - 0.0175i
Mode 4	**Mode 5**	**Mode 6**
-0.0038 + 0.0051i	0.0295 + 0.0062i	-0.0039 - 0.0038i
-0.0004 + 0.0009i	-0.0733 - 0.0157i	0.0026 + 0.0026i
0.0069 - 0.0073i	0.0500 + 0.0106i	-0.0051 - 0.0053i
-0.0233 + 0.0276i	0.0231 + 0.0050i	0.0197 + 0.0191i
-0.0002 + 0.0000i	-0.0241 - 0.0050i	-0.0094 - 0.0091i
0.0231 - 0.0265i	0.0030 + 0.0006i	0.0209 + 0.0213i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 20

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.5484	0.3608	98.3911	0.6060	0.5073	0.2814
2	11.6686	0.3077	98.0809	0.8341	0.7879	**Modal Density**
3	11.8219	0.3905	94.6865	0.8587	1.0460	1.2685
4	15.3723	0.2652	82.6745	0.7163	0.5552	**File Name**
5	13.2835	0.2784	98.6678	0.7820	0.6662	analy_green_20
6	15.8875	0.2719	95.8847	0.5982	0.4368	



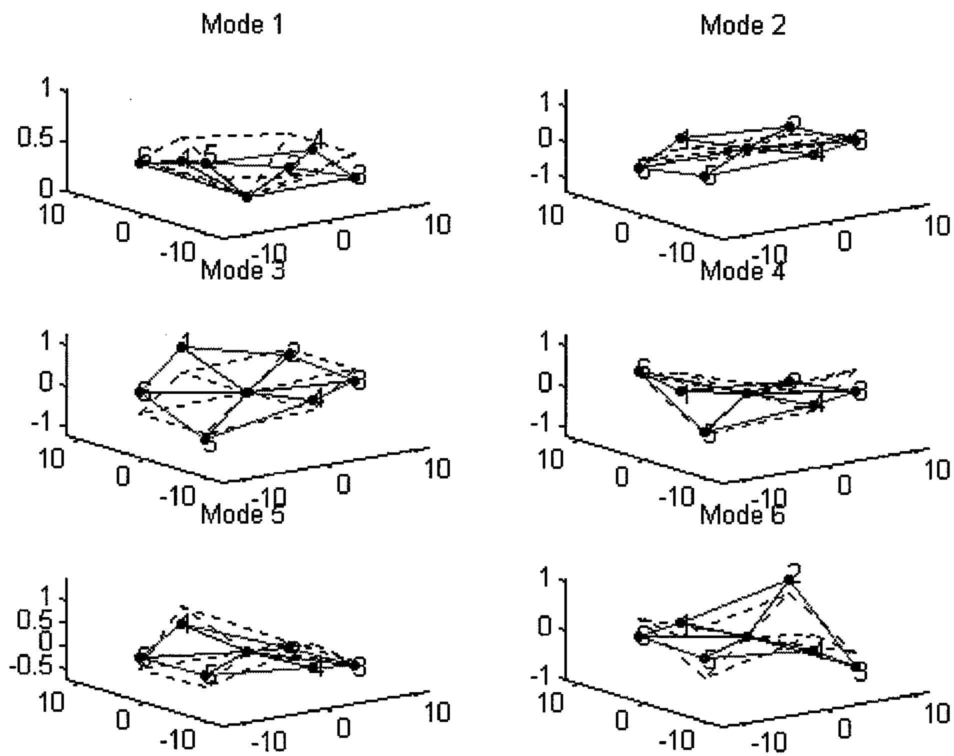
Mode 1	Mode2	Mode 3
0.0118 + 0.0390i	-0.0028 + 0.0322i	-0.0218 + 0.0086i
0.0090 + 0.0303i	-0.0014 + 0.0176i	0.0455 - 0.0190i
0.0049 + 0.0154i	0.0015 - 0.0112i	0.0353 - 0.0148i
0.0065 + 0.0201i	0.0046 - 0.0463i	0.0211 - 0.0083i
0.0065 + 0.0213i	0.0039 - 0.0409i	-0.0340 + 0.0152i
0.0066 + 0.0211i	0.0002 - 0.0036i	-0.0355 + 0.0147i
Mode 4	Mode 5	Mode 6
-0.0021 + 0.0126i	0.0319 + 0.0214i	-0.0068 - 0.0077i
-0.0027 + 0.0122i	-0.0440 - 0.0298i	0.0127 + 0.0153i
0.0071 - 0.0352i	0.0012 + 0.0010i	-0.0248 - 0.0307i
-0.0008 + 0.0064i	0.0448 + 0.0306i	0.0132 + 0.0159i
-0.0047 + 0.0246i	-0.0413 - 0.0278i	-0.0104 - 0.0122i
0.0113 - 0.0576i	-0.0146 - 0.0098i	0.0151 + 0.0178i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.4247	0.4947	98.3318	0.6605	0.6991	0.6026
2	11.1837	0.3397	98.1394	0.9072	0.8184	**Modal Density**
3	11.9249	0.4191	99.1996	0.8968	1.2016	1.0019
4	14.2751	0.3188	98.5657	0.6444	0.5856	**File Name**
5	13.0151	0.2678	98.8847	1.0661	1.0044	analy_green_21
6	14.7497	0.2081	97.7353	0.5933	0.5741	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 21

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



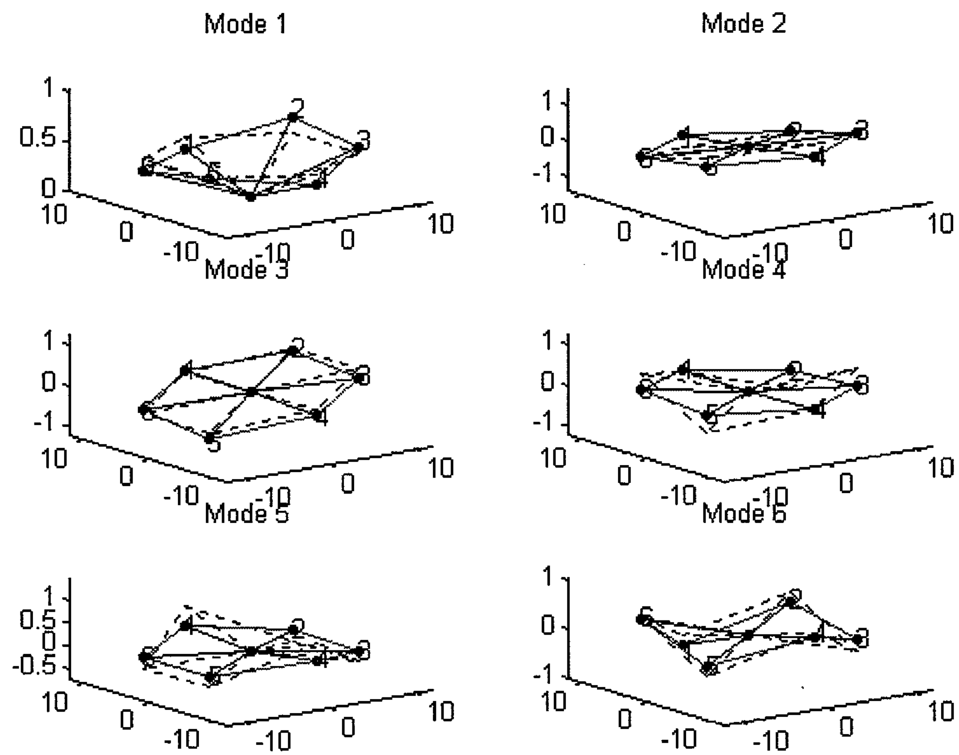
Mode 1	Mode2	Mode 3
0.0080 - 0.0027i	-0.0183 - 0.0182i	0.0526 + 0.0060i
0.0040 - 0.0015i	-0.0040 - 0.0038i	0.0278 + 0.0028i
0.0080 - 0.0017i	0.0050 + 0.0048i	0.0153 + 0.0016i
0.0330 - 0.0059i	0.0220 + 0.0221i	0.0215 + 0.0024i
0.0280 - 0.0055i	-0.0089 - 0.0084i	-0.0527 - 0.0063i
0.0185 - 0.0047i	-0.0290 - 0.0288i	0.0029 + 0.0004i
Mode 4	Mode 5	Mode 6
-0.0451 + 0.0185i	0.0131 - 0.0195i	-0.0055 - 0.0009i
-0.0285 + 0.0118i	-0.0314 + 0.0444i	0.0281 + 0.0046i
-0.0046 + 0.0018i	-0.0267 + 0.0385i	-0.0274 - 0.0047i
0.0156 - 0.0064i	0.0053 - 0.0081i	0.0036 + 0.0004i
-0.0421 + 0.0175i	-0.0010 + 0.0011i	-0.0009 - 0.0002i
0.0544 - 0.0220i	-0.0034 + 0.0050i	0.0011 + 0.0001i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 22

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.8564	0.5072	96.7790	0.6034	0.4869	0.0028
2	10.7960	0.2105	97.9101	0.8396	0.7431	**Modal Density**
3	11.8784	0.3359	98.1983	0.7952	0.7591	1.7786
4	12.8415	0.2710	99.0174	0.8159	0.9198	**File Name**
5	14.4103	0.3444	92.5689	0.8110	0.6137	analy_green_22
6	16.4297	0.2379	93.6611	0.5795	0.3523	



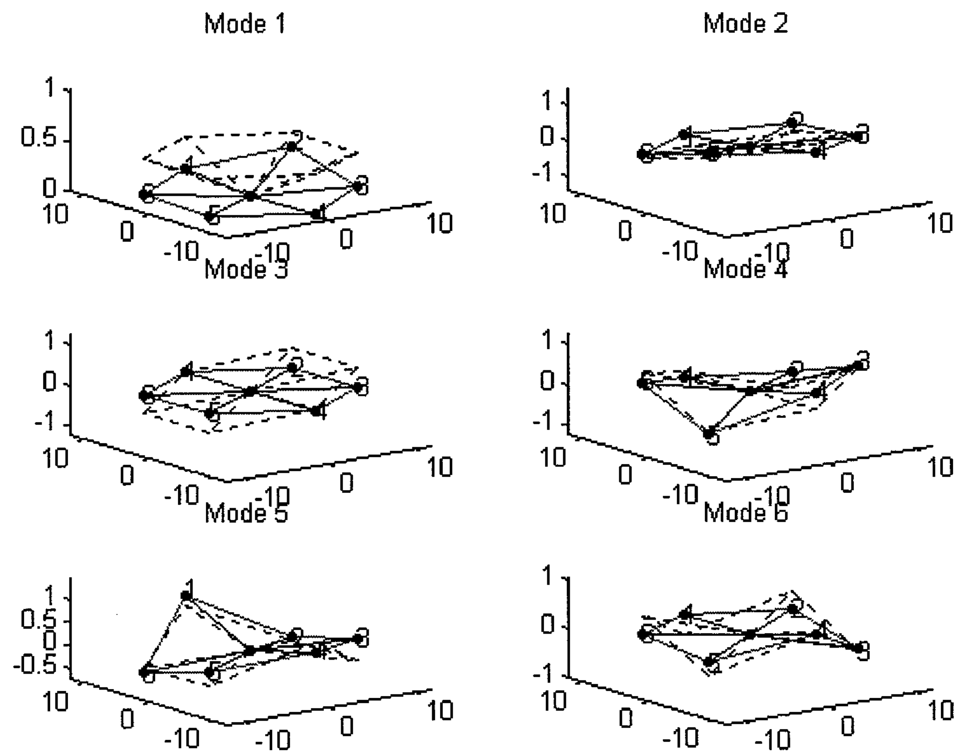
Mode 1	Mode2	Mode 3
0.0183 + 0.0022i	-0.0202 + 0.0296i	0.0009 - 0.0006i
0.0376 + 0.0051i	-0.0187 + 0.0273i	0.0277 - 0.0129i
0.0307 + 0.0041i	0.0228 - 0.0326i	0.0163 - 0.0073i
0.0212 + 0.0030i	0.0184 - 0.0277i	-0.0087 + 0.0036i
0.0267 + 0.0032i	0.0051 - 0.0079i	-0.0413 + 0.0181i
0.0195 + 0.0023i	-0.0185 + 0.0273i	-0.0247 + 0.0109i
Mode 4	**Mode 5**	**Mode 6**
0.0030 + 0.0229i	0.0109 + 0.0379i	-0.0410 - 0.0253i
-0.0059 - 0.0394i	-0.0015 - 0.0056i	0.0143 + 0.0083i
0.0050 + 0.0328i	-0.0056 - 0.0183i	-0.0100 - 0.0059i
-0.0003 - 0.0040i	0.0179 + 0.0611i	0.0229 + 0.0138i
-0.0058 - 0.0411i	-0.0046 - 0.0159i	-0.0124 - 0.0081i
0.0080 + 0.0590i	-0.0035 - 0.0124i	0.0231 + 0.0141i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 23

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2144	0.4259	98.4176	0.7055	0.7737	0.7123
2	11.6900	0.3683	99.2080	1.1458	1.2547	**Modal Density**
3	10.8476	0.3500	95.1596	0.7106	0.7462	0.9959
4	12.6993	0.2891	99.3020	0.7750	0.9263	**File Name**
5	14.0182	0.3080	98.8527	0.7282	0.5449	analy_green_23
6	14.4305	0.2818	98.7776	0.5617	0.4894	



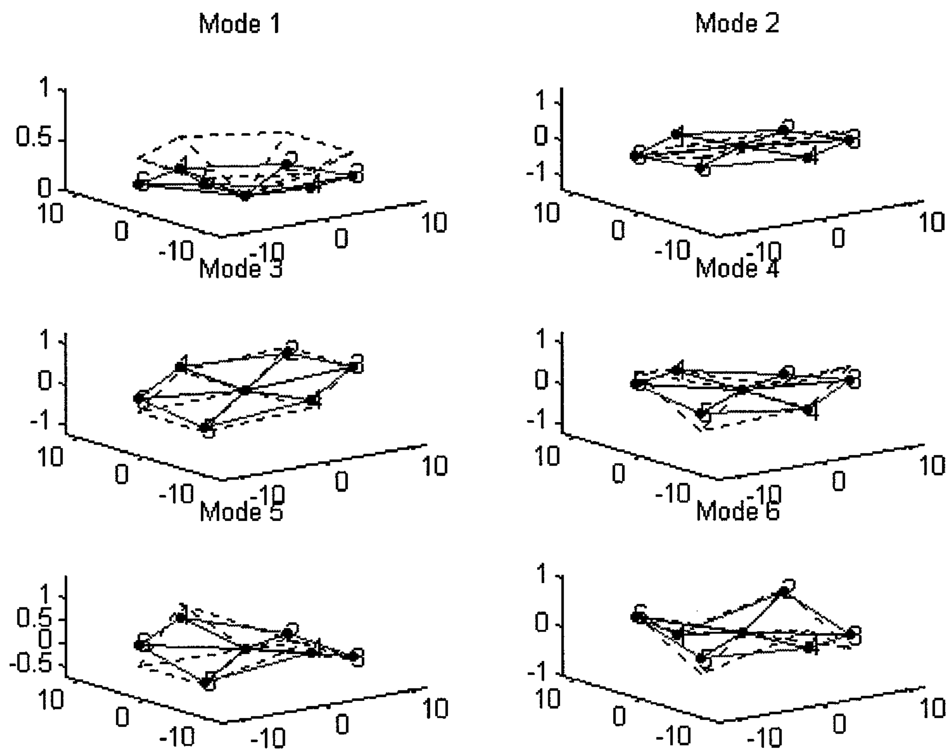
Mode 1	Mode2	Mode 3
0.0058 + 0.0187i	-0.0286 - 0.0370i	-0.0004 - 0.0185i
0.0172 + 0.0516i	0.0024 + 0.0032i	0.0010 + 0.0172i
0.0041 + 0.0124i	0.0197 + 0.0244i	-0.0001 + 0.0014i
0.0013 + 0.0047i	0.0377 + 0.0478i	-0.0008 - 0.0118i
0.0014 + 0.0048i	0.0407 + 0.0526i	-0.0014 - 0.0351i
0.0030 + 0.0098i	-0.0179 - 0.0226i	-0.0014 - 0.0537i
Mode 4	Mode 5	Mode 6
-0.0088 + 0.0041i	0.0576 - 0.0130i	-0.0010 - 0.0015i
-0.0052 + 0.0021i	-0.0146 + 0.0037i	0.0019 + 0.0032i
0.0341 - 0.0153i	0.0130 - 0.0029i	-0.0147 - 0.0212i
0.0249 - 0.0105i	0.0272 - 0.0062i	0.0148 + 0.0225i
-0.0330 + 0.0151i	0.0023 - 0.0004i	-0.0053 - 0.0077i
0.0154 - 0.0082i	-0.0276 + 0.0062i	0.0010 + 0.0024i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 24

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1985	0.3271	96.0923	0.4546	0.2509	0.2624
2	13.0380	0.3584	99.3027	0.9568	0.9278	**Modal Density**
3	11.4841	0.4711	98.4897	0.6513	0.5955	1.6406
4	14.7229	0.2459	96.8504	0.8326	0.8691	**File Name**
5	14.2777	0.3133	97.7435	0.7232	0.5552	analy_green_24
6	16.5723	0.2611	96.3157	0.5870	0.3850	



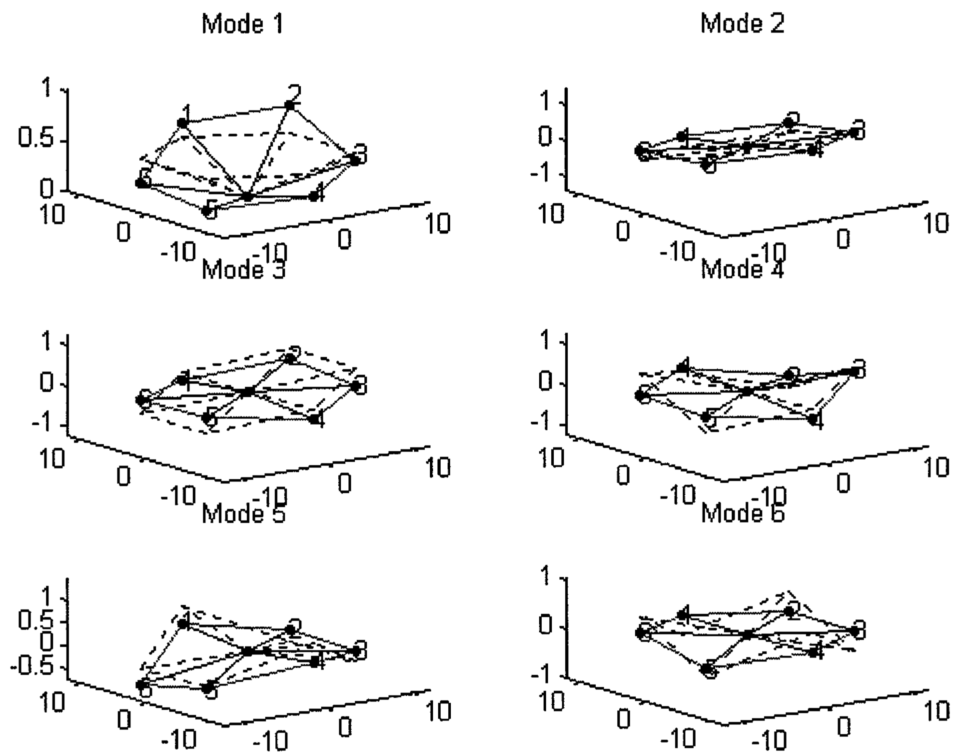
Mode 1	Mode2	Mode 3
0.0057 + 0.0086i	-0.0229 + 0.0478i	0.0071 - 0.0068i
0.0066 + 0.0103i	-0.0166 + 0.0350i	0.0262 - 0.0235i
0.0107 + 0.0168i	0.0021 - 0.0040i	0.0337 - 0.0295i
0.0185 + 0.0297i	0.0170 - 0.0353i	0.0141 - 0.0112i
0.0224 + 0.0385i	-0.0005 + 0.0004i	-0.0295 + 0.0261i
0.0096 + 0.0164i	-0.0166 + 0.0340i	-0.0116 + 0.0099i
Mode 4	Mode 5	Mode 6
-0.0029 + 0.0088i	0.0242 - 0.0346i	-0.0235 + 0.0255i
-0.0182 + 0.0483i	-0.0121 + 0.0176i	0.0185 - 0.0206i
0.0121 - 0.0334i	-0.0216 + 0.0312i	-0.0068 + 0.0075i
-0.0045 + 0.0127i	0.0335 - 0.0485i	0.0036 - 0.0045i
-0.0047 + 0.0126i	-0.0211 + 0.0307i	-0.0053 + 0.0051i
0.0192 - 0.0512i	0.0159 - 0.0228i	0.0188 - 0.0194i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 25

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.4435	0.5405	98.1960	0.5954	0.5158	0.4692
2	12.1048	0.3549	92.4647	0.9307	0.9151	**Modal Density**
3	11.5542	0.3249	98.3876	0.8234	0.9123	1.0753
4	13.9950	0.2514	99.4201	0.7846	0.7654	**File Name**
5	13.3993	0.3032	99.6138	0.9455	1.0816	analy_green_25
6	15.0446	0.1869	97.8638	0.6335	0.5400	



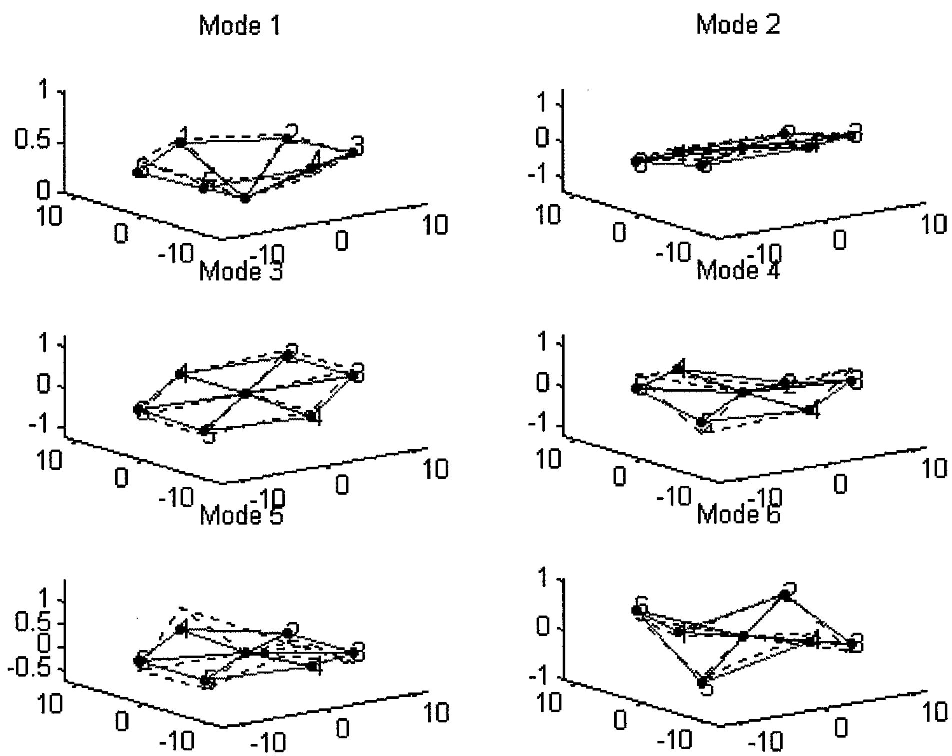
Mode 1	Mode2	Mode 3
0.0303 - 0.0054i	-0.0200 + 0.0261i	-0.0157 + 0.0305i
0.0387 - 0.0068i	-0.0001 + 0.0011i	0.0188 - 0.0390i
0.0188 - 0.0033i	0.0180 - 0.0244i	0.0027 - 0.0052i
0.0113 - 0.0025i	0.0244 - 0.0353i	-0.0152 + 0.0329i
0.0047 - 0.0007i	0.0053 - 0.0079i	-0.0078 + 0.0177i
0.0100 - 0.0012i	-0.0049 + 0.0062i	-0.0092 + 0.0215i
Mode 4	**Mode 5**	**Mode 6**
0.0072 + 0.0122i	0.0180 - 0.0155i	-0.0009 - 0.0029i
-0.0163 - 0.0261i	-0.0030 + 0.0027i	-0.0004 + 0.0004i
0.0300 + 0.0494i	-0.0064 + 0.0054i	-0.0007 - 0.0015i
-0.0181 - 0.0294i	0.0166 - 0.0142i	0.0014 + 0.0065i
-0.0094 - 0.0164i	-0.0338 + 0.0279i	-0.0109 - 0.0390i
-0.0019 - 0.0051i	-0.0666 + 0.0553i	0.0030 + 0.0186i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 26

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	9.5933	0.3030	93.9368	0.5800	0.4695	8.4047e-004
2	10.5819	0.3451	93.3816	0.8505	0.7369	**Modal Density**
3	11.1867	0.3563	97.2571	0.8423	1.0018	1.7143
4	12.5380	0.2867	99.1516	0.6740	0.6748	**File Name**
5	13.3197	0.4090	98.6967	0.6849	0.4603	analy_green_26
6	15.8050	0.3832	91.2176	0.4568	0.2494	



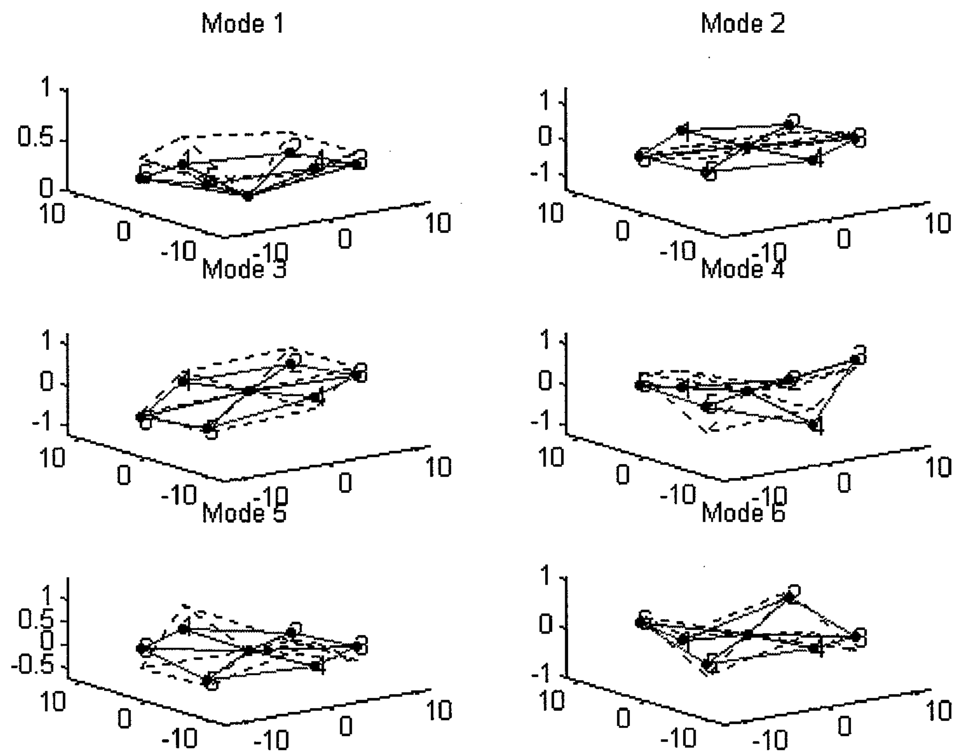
Mode 1	Mode2	Mode 3
0.0224 - 0.0081i	-0.0423 + 0.0005i	-0.0001 - 0.0005i
0.0218 - 0.0071i	-0.0170 + 0.0010i	0.0259 + 0.0245i
0.0253 - 0.0090i	0.0144 - 0.0001i	0.0248 + 0.0240i
0.0299 - 0.0100i	0.0333 - 0.0013i	-0.0102 - 0.0091i
0.0201 - 0.0072i	0.0077 - 0.0011i	-0.0320 - 0.0308i
0.0174 - 0.0063i	-0.0202 - 0.0011i	-0.0264 - 0.0254i
Mode 4	Mode 5	Mode 6
0.0080 + 0.0154i	0.0076 - 0.0360i	-0.0268 + 0.0072i
-0.0326 - 0.0632i	-0.0032 + 0.0114i	0.0296 - 0.0081i
0.0181 + 0.0354i	-0.0055 + 0.0295i	-0.0190 + 0.0056i
0.0000 - 0.0003i	0.0093 - 0.0442i	0.0223 - 0.0057i
-0.0213 - 0.0414i	-0.0070 + 0.0298i	-0.0453 + 0.0115i
0.0176 + 0.0345i	-0.0072 + 0.0363i	0.0478 - 0.0121i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 27

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.0114	0.4039	97.4346	0.7773	0.8912	0.8425
2	10.8088	0.4104	98.0699	0.8490	0.7899	**Modal Density**
3	11.2418	0.3497	88.7018	0.8689	1.0145	0.8880
4	13.1038	0.2994	94.1208	0.7242	0.8012	**File Name**
5	12.5683	0.2687	98.9247	1.0503	1.1867	analy_green_27
6	13.7561	0.2645	99.0363	0.7051	0.6958	



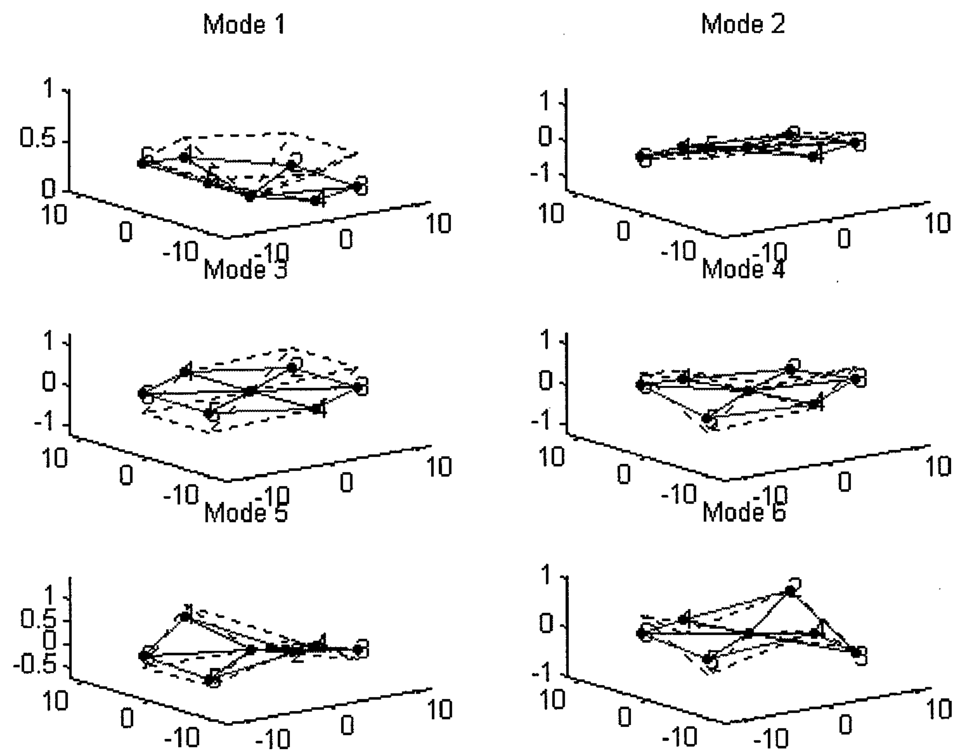
Mode 1	Mode2	Mode 3
0.0078 + 0.0071i	-0.0098 - 0.0274i	-0.0170 - 0.0151i
0.0126 + 0.0111i	-0.0045 - 0.0499i	0.0063 - 0.0075i
0.0161 + 0.0149i	0.0059 - 0.0154i	0.0205 + 0.0079i
0.0278 + 0.0255i	0.0110 + 0.0255i	0.0197 + 0.0149i
0.0202 + 0.0175i	-0.0070 + 0.0177i	-0.0256 - 0.0104i
0.0125 + 0.0110i	-0.0162 - 0.0089i	-0.0417 - 0.0243i
Mode 4	Mode 5	Mode 6
-0.0378 + 0.0105i	0.0073 + 0.0269i	-0.0349 - 0.0371i
-0.0293 + 0.0087i	-0.0082 - 0.0370i	0.0177 + 0.0187i
0.0673 - 0.0196i	0.0006 + 0.0116i	-0.0086 - 0.0095i
-0.0370 + 0.0109i	0.0073 + 0.0244i	0.0048 + 0.0052i
0.0150 - 0.0045i	-0.0174 - 0.0712i	-0.0096 - 0.0101i
0.0210 - 0.0059i	0.0106 + 0.0469i	0.0176 + 0.0196i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 28

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2676	0.3265	97.3858	0.6210	0.6148	0.2006
2	11.4265	0.2015	98.6209	0.8242	0.8229	**Modal Density**
3	11.4461	0.2450	98.1980	0.7179	0.8359	0.9919
4	13.3326	0.3371	99.4023	0.6986	0.7699	**File Name**
5	13.2201	0.3116	99.5127	0.8138	0.7640	analy_green_28
6	14.4910	0.3860	97.1372	0.5292	0.4105	



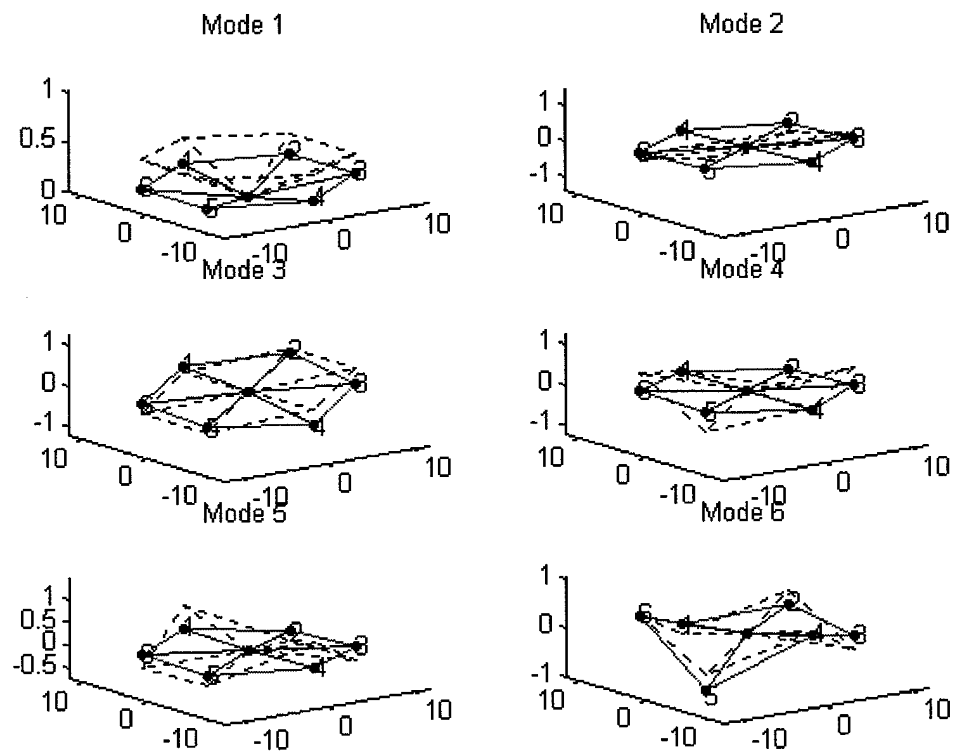
Mode 1	Mode2	Mode 3
0.0126 + 0.0170i	-0.0414 - 0.0176i	0.0006 - 0.0135i
0.0062 + 0.0082i	-0.0245 - 0.0103i	0.0017 - 0.0478i
0.0043 + 0.0060i	-0.0017 - 0.0012i	0.0013 - 0.0467i
0.0094 + 0.0125i	0.0194 + 0.0072i	0.0012 - 0.0394i
0.0229 + 0.0307i	0.0386 + 0.0157i	0.0001 - 0.0031i
0.0230 + 0.0312i	-0.0170 - 0.0078i	-0.0015 + 0.0394i
Mode 4	**Mode 5**	**Mode 6**
-0.0192 - 0.0481i	0.0266 + 0.0202i	-0.0065 - 0.0059i
-0.0023 - 0.0048i	-0.0432 - 0.0336i	0.0200 + 0.0171i
0.0170 + 0.0426i	-0.0060 - 0.0043i	-0.0251 - 0.0208i
0.0125 + 0.0319i	0.0417 + 0.0334i	0.0193 + 0.0164i
-0.0160 - 0.0396i	-0.0122 - 0.0097i	-0.0049 - 0.0039i
0.0186 + 0.0466i	-0.0047 - 0.0034i	0.0022 + 0.0020i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.2190	0.1918	98.2041	0.6514	0.5195	0.3070
2	11.4680	0.4992	97.6483	0.9301	0.8707	**Modal Density**
3	11.9399	0.4683	98.5821	0.9220	1.0160	1.1756
4	13.1254	0.3210	99.4655	0.9803	1.1764	**File Name**
5	13.8648	0.2253	98.0279	0.9011	0.7222	analy_green_29
6	15.0731	0.4484	95.9945	0.6289	0.5223	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 29

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30



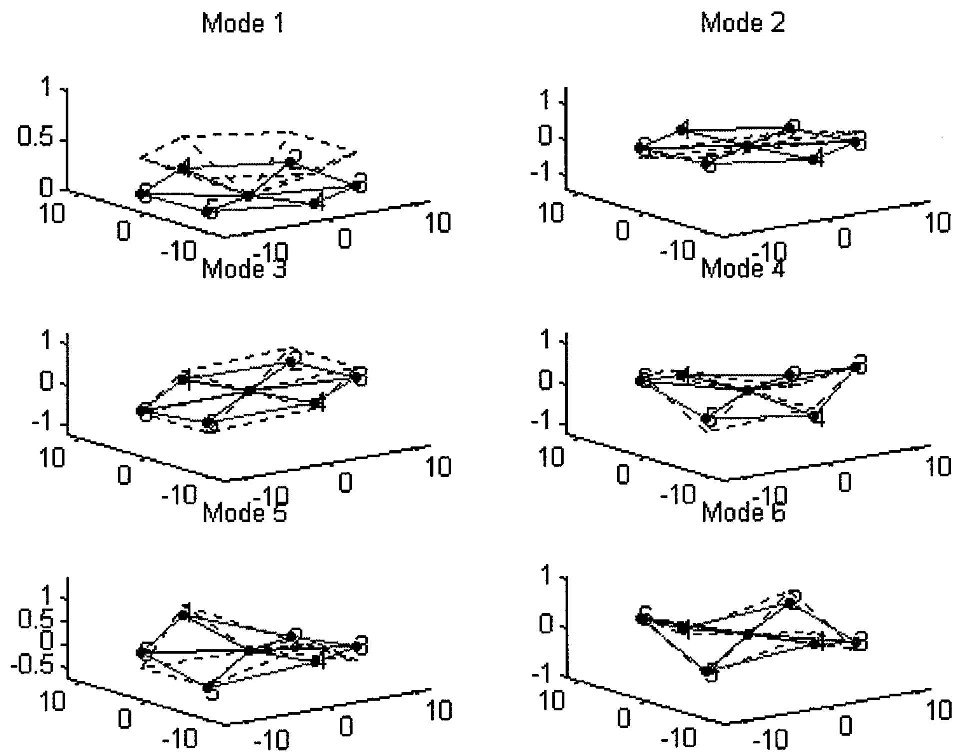
Mode 1	Mode2	Mode 3
0.0090 - 0.0197i	-0.0077 - 0.0417i	0.0109 - 0.0107i
0.0125 - 0.0271i	-0.0010 - 0.0074i	0.0286 - 0.0296i
0.0124 - 0.0300i	0.0059 + 0.0293i	0.0070 - 0.0079i
0.0101 - 0.0239i	0.0041 + 0.0243i	-0.0274 + 0.0285i
0.0062 - 0.0143i	-0.0023 - 0.0098i	-0.0272 + 0.0287i
0.0066 - 0.0159i	-0.0081 - 0.0428i	-0.0191 + 0.0211i
Mode 4	**Mode 5**	**Mode 6**
-0.0031 - 0.0306i	0.0069 - 0.0563i	-0.0133 + 0.0061i
-0.0021 - 0.0275i	-0.0072 + 0.0600i	0.0091 - 0.0039i
0.0041 + 0.0468i	0.0022 - 0.0204i	-0.0072 + 0.0037i
-0.0047 - 0.0541i	0.0017 - 0.0121i	0.0201 - 0.0085i
-0.0003 - 0.0038i	-0.0051 + 0.0431i	-0.0456 + 0.0205i
0.0044 + 0.0506i	-0.0018 + 0.0119i	0.0252 - 0.0113i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 30

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.3394	0.2856	96.1604	0.7570	0.8049	0.0720
2	11.2873	0.3801	98.8103	0.9701	0.8933	**Modal Density**
3	11.6458	0.3734	98.1685	0.9386	1.0521	0.9699
4	13.0681	0.3050	99.4447	0.8964	1.0314	**File Name**
5	13.5172	0.2693	99.5572	0.9297	0.8163	analy_green_30
6	14.5117	0.3475	98.1691	0.5236	0.3962	



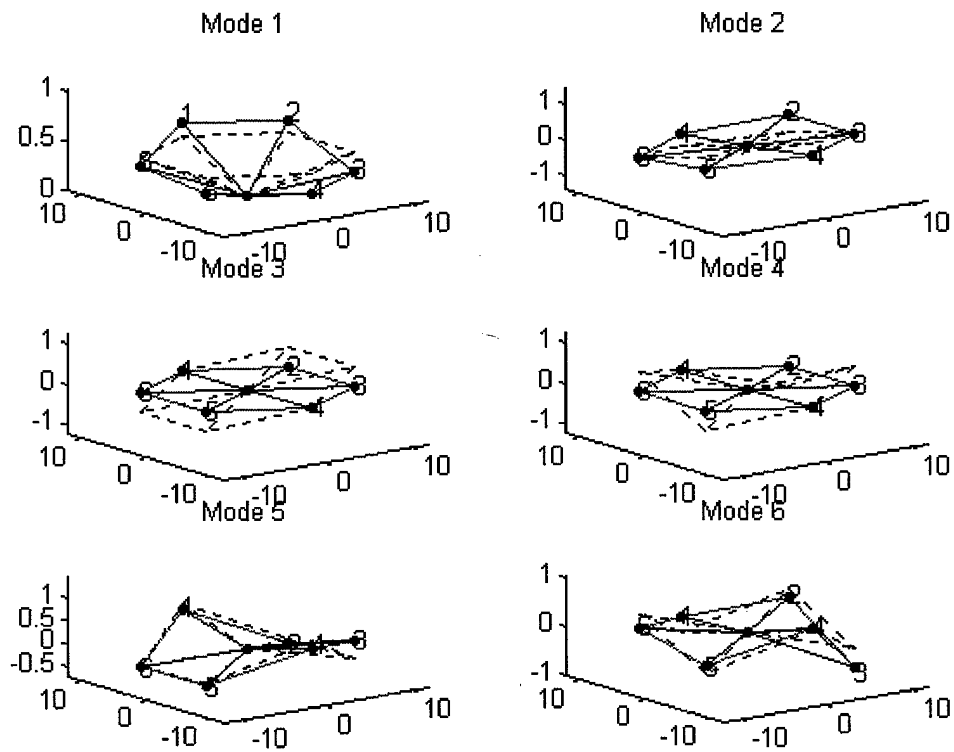
Mode 1	Mode2	Mode 3
0.0051 + 0.0211i	-0.0069 + 0.0240i	-0.0160 + 0.0206i
0.0079 + 0.0319i	-0.0110 + 0.0377i	0.0104 - 0.0150i
0.0047 + 0.0235i	-0.0002 + 0.0004i	0.0161 - 0.0203i
0.0074 + 0.0329i	0.0096 - 0.0336i	0.0112 - 0.0140i
0.0050 + 0.0230i	0.0064 - 0.0224i	-0.0176 + 0.0234i
0.0034 + 0.0181i	0.0000 + 0.0009i	-0.0301 + 0.0385i
Mode 4	Mode 5	Mode 6
-0.0133 - 0.0151i	0.0316 - 0.0498i	-0.0245 - 0.0290i
-0.0187 - 0.0211i	-0.0184 + 0.0295i	0.0147 + 0.0168i
0.0476 + 0.0547i	0.0000 + 0.0008i	-0.0184 - 0.0196i
-0.0182 - 0.0210i	0.0168 - 0.0274i	0.0143 + 0.0163i
-0.0140 - 0.0159i	-0.0319 + 0.0500i	-0.0258 - 0.0300i
0.0308 + 0.0356i	0.0012 - 0.0009i	0.0292 + 0.0345i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1321	0.2322	97.4444	0.7798	0.8385	0.4518
2	10.8775	0.3606	97.6846	0.9215	0.8483	**Modal Density**
3	11.3434	0.4423	98.5372	0.7420	0.9129	0.8658
4	13.1550	0.3489	98.9580	0.6860	0.7168	**File Name**
5	12.8352	0.2474	96.1699	0.9361	0.7912	analy_green_31
6	13.8398	0.2850	98.8942	0.7421	0.7818	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 31

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35



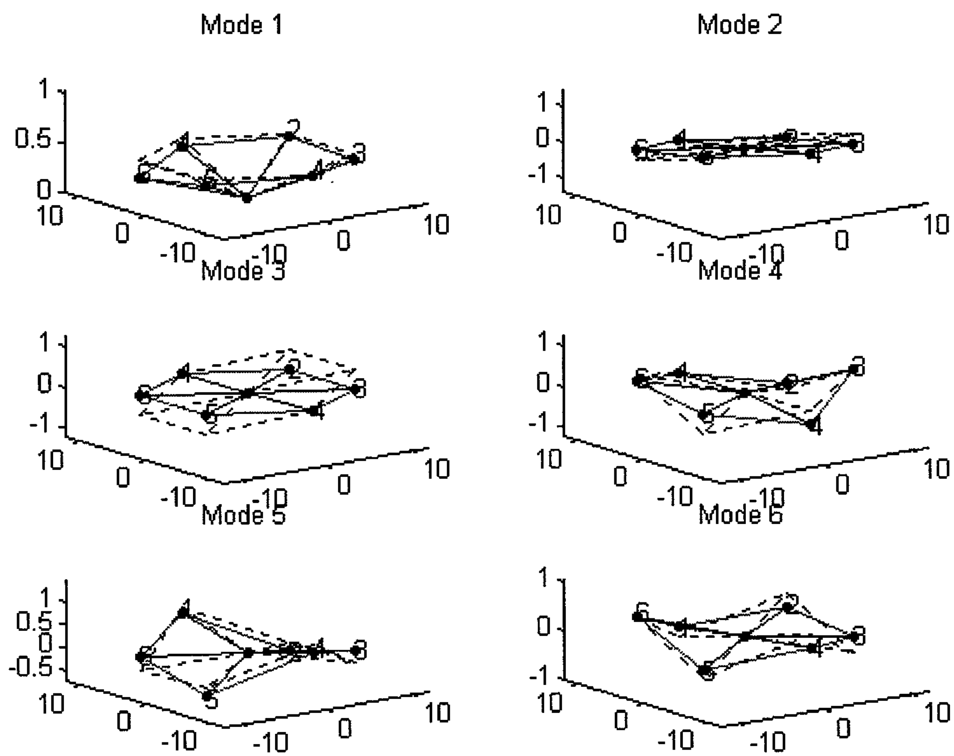
Mode 1	Mode2	Mode 3
0.0345 - 0.0152i	-0.0155 + 0.0254i	-0.0002 + 0.0179i
0.0343 - 0.0150i	0.0159 - 0.0282i	0.0004 + 0.0297i
0.0132 - 0.0057i	0.0131 - 0.0225i	0.0000 - 0.0049i
0.0139 - 0.0062i	0.0148 - 0.0260i	-0.0001 - 0.0407i
0.0155 - 0.0070i	-0.0028 + 0.0039i	0.0001 - 0.0463i
0.0213 - 0.0094i	-0.0172 + 0.0289i	-0.0002 - 0.0202i
Mode 4	**Mode 5**	**Mode 6**
0.0001 + 0.0215i	0.0373 - 0.0246i	-0.0059 - 0.0006i
-0.0002 + 0.0059i	-0.0310 + 0.0209i	0.0163 + 0.0015i
-0.0003 - 0.0338i	0.0083 - 0.0052i	-0.0524 - 0.0056i
-0.0001 - 0.0139i	0.0376 - 0.0248i	0.0280 + 0.0034i
0.0001 + 0.0597i	-0.0283 + 0.0187i	-0.0147 - 0.0014i
-0.0001 - 0.0640i	-0.0267 + 0.0173i	0.0081 + 0.0013i

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1934	0.2978	98.4786	0.6932	0.6268	0.1133
2	11.4846	0.3885	98.1363	1.1729	1.2277	**Modal Density**
3	11.0833	0.2754	98.6749	0.7963	0.8810	1.0125
4	13.4799	0.3105	98.9757	0.7610	0.7257	**File Name**
5	12.6689	0.2890	99.3473	1.1230	1.1890	analy_green_32
6	14.4605	0.3427	98.2019	0.4996	0.3405	

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 32

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 40



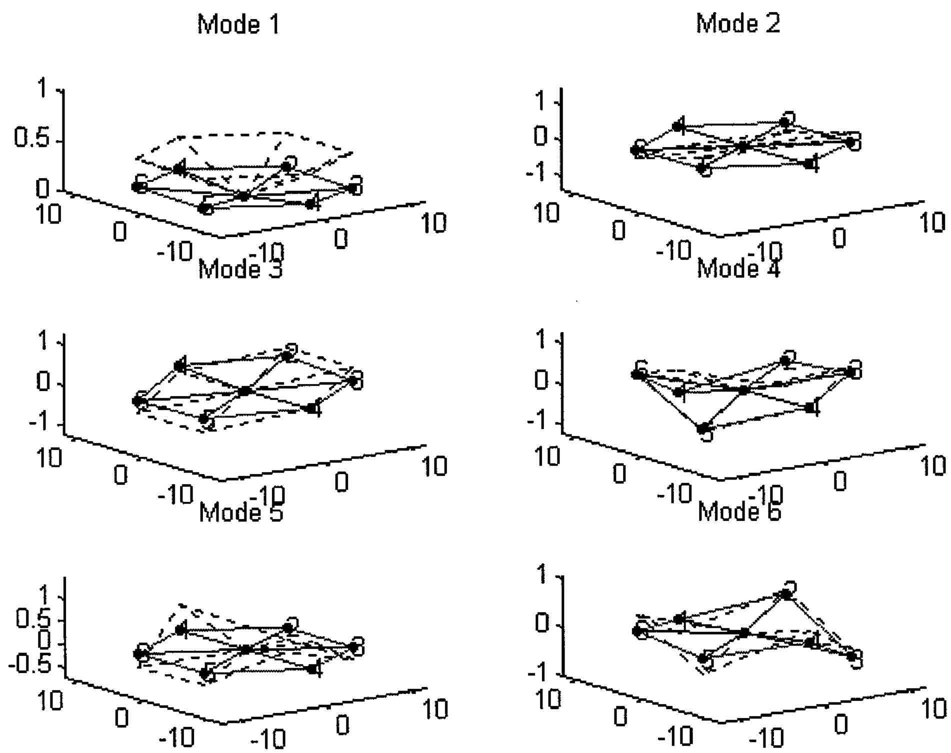
Mode 1	Mode2	Mode 3
0.0219 + 0.0132i	-0.0232 + 0.0242i	-0.0004 - 0.0363i
0.0272 + 0.0166i	-0.0260 + 0.0280i	0.0003 + 0.0172i
0.0246 + 0.0147i	-0.0013 + 0.0016i	0.0008 + 0.0411i
0.0280 + 0.0166i	0.0232 - 0.0251i	0.0001 + 0.0202i
0.0240 + 0.0142i	0.0240 - 0.0262i	-0.0007 - 0.0367i
0.0166 + 0.0097i	0.0002 - 0.0006i	-0.0010 - 0.0430i
Mode 4	**Mode 5**	**Mode 6**
-0.0011 + 0.0004i	0.0450 - 0.0242i	-0.0133 + 0.0195i
-0.0299 + 0.0263i	-0.0429 + 0.0228i	0.0078 - 0.0111i
0.0425 - 0.0368i	-0.0018 + 0.0010i	-0.0053 + 0.0091i
-0.0288 + 0.0240i	0.0430 - 0.0232i	0.0073 - 0.0106i
-0.0018 + 0.0023i	-0.0456 + 0.0247i	-0.0140 + 0.0199i
0.0315 - 0.0281i	-0.0001 + 0.0003i	0.0270 - 0.0376i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 33

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.4918	0.4134	99.0208	0.8609	0.9207	0.4273
2	11.3836	0.2618	91.8925	1.0708	0.9914	**Modal Density**
3	11.7670	0.3697	99.4694	0.9663	1.1835	0.9408
4	13.7273	0.3250	95.1623	0.7931	0.8941	**File Name**
5	13.2498	0.2924	94.2278	1.1173	0.9978	analy_green_33
6	14.6165	0.2125	98.4569	0.5405	0.4411	



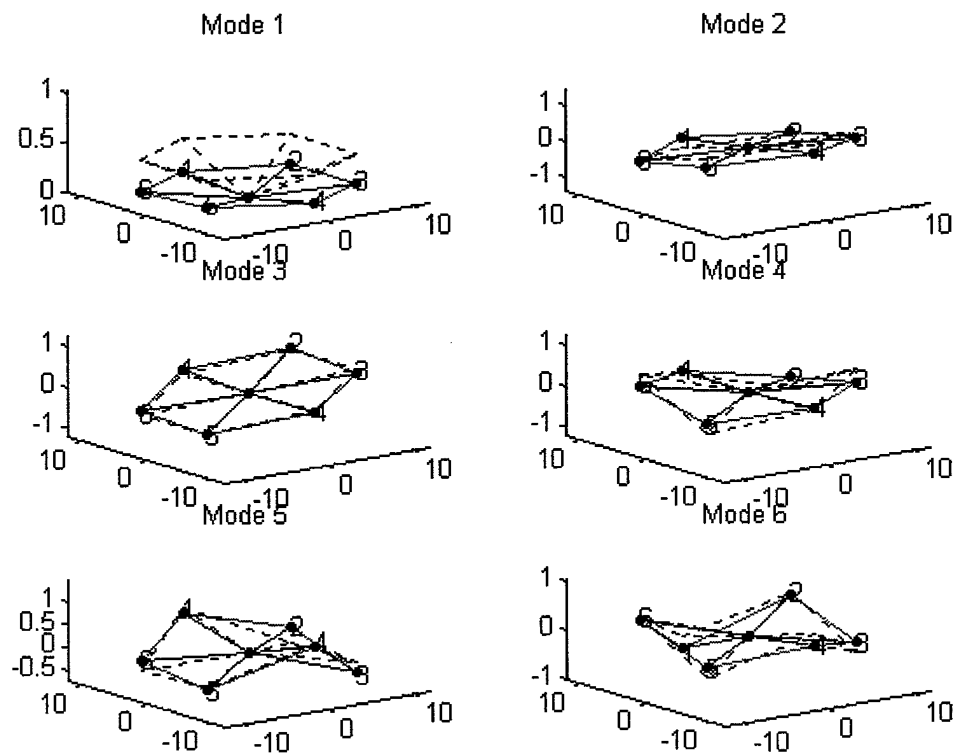
Mode 1	Mode2	Mode 3
0.0052 + 0.0207i	-0.0016 + 0.0317i	0.0085 + 0.0183i
0.0041 + 0.0175i	-0.0009 + 0.0143i	0.0224 + 0.0467i
0.0036 + 0.0138i	0.0006 - 0.0114i	0.0104 + 0.0213i
0.0080 + 0.0308i	0.0021 - 0.0446i	0.0019 + 0.0045i
0.0072 + 0.0292i	0.0002 - 0.0098i	-0.0121 - 0.0246i
0.0081 + 0.0318i	-0.0017 + 0.0325i	-0.0129 - 0.0272i
Mode 4	**Mode 5**	**Mode 6**
-0.0532 - 0.0225i	0.0016 + 0.0470i	-0.0088 - 0.0093i
0.0131 + 0.0059i	-0.0008 - 0.0463i	0.0192 + 0.0194i
0.0346 + 0.0140i	-0.0003 - 0.0090i	-0.0339 - 0.0363i
0.0018 + 0.0008i	0.0011 + 0.0386i	0.0112 + 0.0123i
-0.0450 - 0.0184i	-0.0011 - 0.0664i	-0.0060 - 0.0068i
0.0455 + 0.0191i	0.0002 + 0.0106i	0.0040 + 0.0045i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 34

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1801	0.2537	98.4866	0.7847	0.7855	0.1028
2	11.0222	0.4048	98.5805	0.8662	0.8156	**Modal Density**
3	11.4078	0.3925	98.5582	0.7048	0.7838	1.0589
4	13.3633	0.3058	96.6642	0.8546	0.9629	**File Name**
5	13.0665	0.2858	99.5632	0.8890	0.8758	analy_green_34
6	14.6073	0.2554	97.6202	0.5048	0.3510	



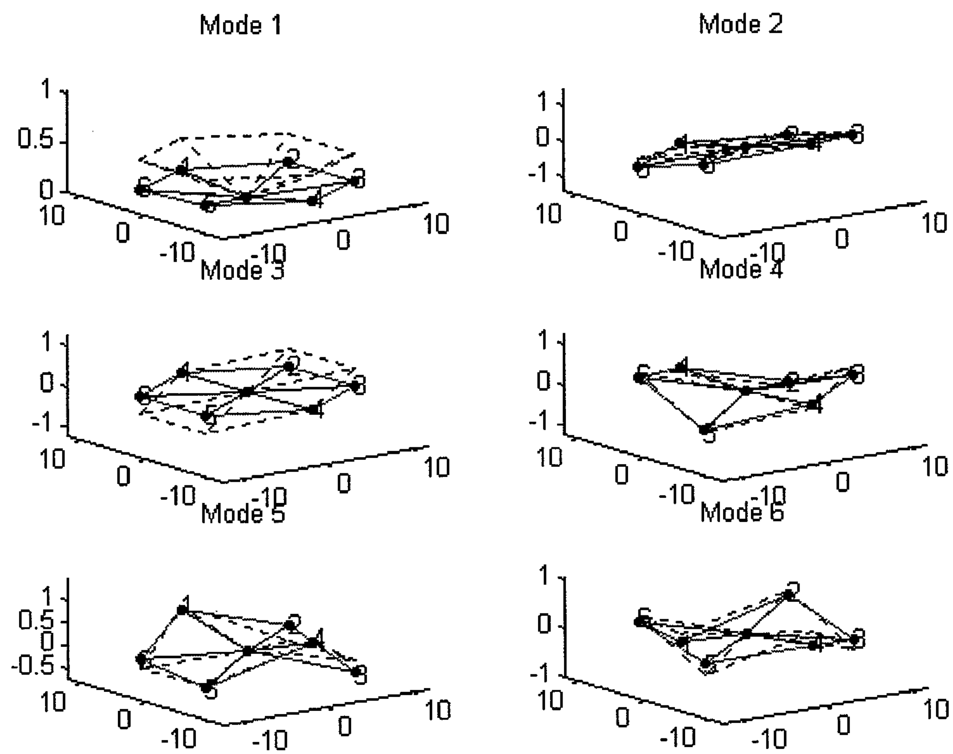
Mode 1	Mode2	Mode 3
0.0051 - 0.0179i	-0.0222 + 0.0298i	0.0049 - 0.0018i
0.0077 - 0.0263i	-0.0172 + 0.0229i	0.0404 - 0.0167i
0.0073 - 0.0262i	0.0105 - 0.0137i	0.0275 - 0.0114i
0.0094 - 0.0333i	0.0268 - 0.0350i	-0.0035 + 0.0013i
0.0090 - 0.0320i	0.0038 - 0.0055i	-0.0358 + 0.0145i
0.0072 - 0.0257i	-0.0237 + 0.0309i	-0.0298 + 0.0121i
Mode 4	**Mode 5**	**Mode 6**
0.0046 - 0.0098i	0.0395 + 0.0187i	-0.0420 + 0.0213i
-0.0198 + 0.0459i	0.0060 + 0.0028i	0.0220 - 0.0114i
0.0156 - 0.0368i	-0.0435 - 0.0203i	-0.0128 + 0.0070i
0.0053 - 0.0116i	0.0487 + 0.0230i	0.0102 - 0.0053i
-0.0247 + 0.0562i	-0.0282 - 0.0132i	-0.0133 + 0.0068i
0.0209 - 0.0475i	-0.0086 - 0.0039i	0.0226 - 0.0115i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 35

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 25

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.5142	0.5073	98.9529	0.8217	0.8930	0.6173
2	11.6942	0.3319	99.2234	1.0147	1.0305	**Modal Density**
3	11.4345	0.2605	97.8404	0.8377	0.9301	0.9170
4	13.3122	0.2985	99.2311	0.8478	0.9692	**File Name**
5	13.6309	0.2955	98.7470	0.9715	0.9213	analy_green_35
6	14.5576	0.2811	98.2196	0.5511	0.4676	



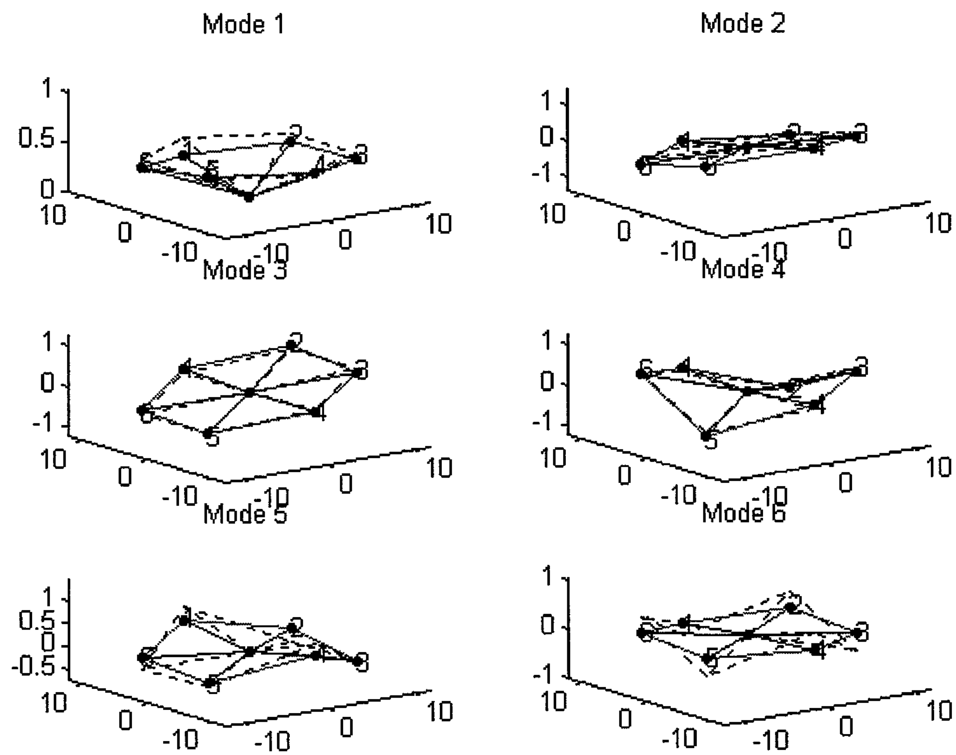
Mode 1	Mode2	Mode 3
0.0062 - 0.0175i	-0.0359 - 0.0101i	0.0003 - 0.0056i
0.0088 - 0.0256i	-0.0269 - 0.0069i	0.0030 - 0.0431i
0.0087 - 0.0259i	0.0161 + 0.0056i	0.0018 - 0.0292i
0.0109 - 0.0328i	0.0431 + 0.0130i	0.0000 + 0.0046i
0.0108 - 0.0312i	0.0069 + 0.0010i	-0.0026 + 0.0391i
0.0085 - 0.0253i	-0.0371 - 0.0122i	-0.0024 + 0.0321i
Mode 4	**Mode 5**	**Mode 6**
0.0080 - 0.0065i	0.0436 + 0.0094i	-0.0364 + 0.0297i
-0.0356 + 0.0322i	0.0066 + 0.0025i	0.0199 - 0.0161i
0.0276 - 0.0258i	-0.0472 - 0.0100i	-0.0119 + 0.0097i
0.0108 - 0.0094i	0.0523 + 0.0111i	0.0091 - 0.0075i
-0.0462 + 0.0418i	-0.0297 - 0.0060i	-0.0116 + 0.0089i
0.0385 - 0.0349i	-0.0097 - 0.0021i	0.0193 - 0.0157i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 35r1

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 45

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.5262	0.4622	98.3323	0.8202	0.8936	0.6266
2	11.7047	0.3102	98.4336	0.9980	1.0123	**Modal Density**
3	11.4244	0.2020	98.6614	0.8467	0.9347	0.9120
4	13.3208	0.2781	99.0378	0.8275	0.9491	**File Name**
5	13.6199	0.2845	99.3720	0.9802	0.9228	analy_green_35r1
6	14.5551	0.3347	97.6421	0.5545	0.4759	



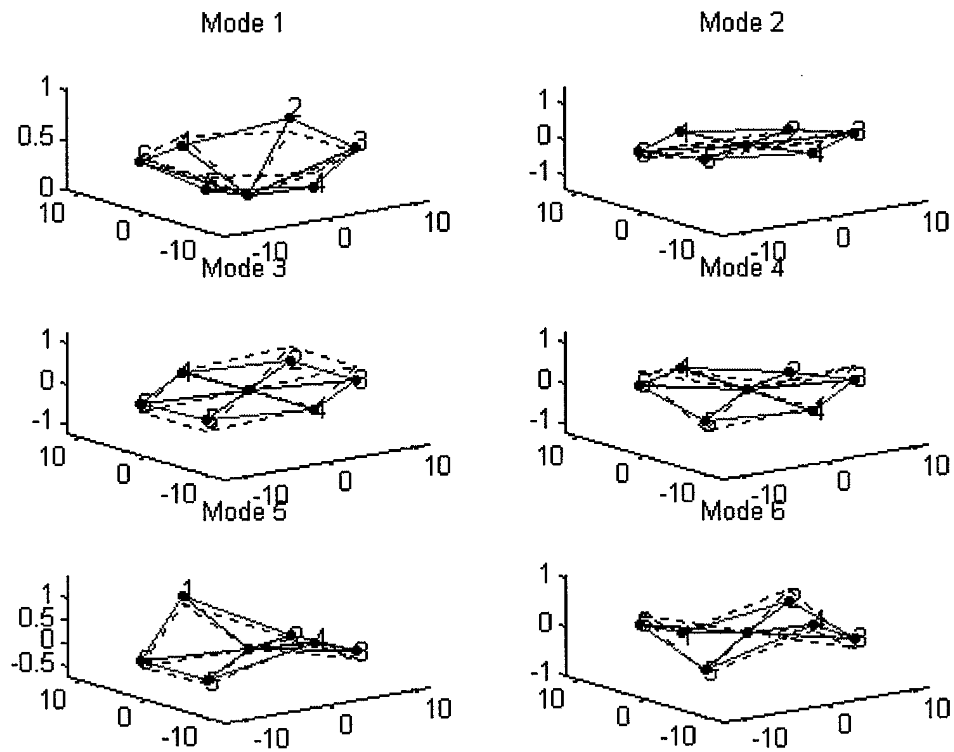
Mode 1	Mode2	Mode 3
0.0159 + 0.0088i	-0.0302 - 0.0205i	0.0056 - 0.0015i
0.0237 + 0.0129i	-0.0237 - 0.0160i	0.0412 - 0.0153i
0.0239 + 0.0128i	0.0141 + 0.0103i	0.0278 - 0.0106i
0.0312 + 0.0174i	0.0357 + 0.0245i	-0.0035 + 0.0007i
0.0295 + 0.0162i	0.0053 + 0.0025i	-0.0363 + 0.0126i
0.0233 + 0.0122i	-0.0320 - 0.0231i	-0.0297 + 0.0110i
Mode 4	Mode 5	Mode 6
0.0086 - 0.0009i	0.0243 - 0.0366i	-0.0117 - 0.0476i
-0.0489 + 0.0052i	0.0027 - 0.0038i	0.0063 + 0.0248i
0.0413 - 0.0043i	-0.0263 + 0.0390i	-0.0033 - 0.0144i
0.0102 - 0.0014i	0.0303 - 0.0453i	0.0025 + 0.0115i
-0.0603 + 0.0063i	-0.0184 + 0.0281i	-0.0034 - 0.0146i
0.0522 - 0.0055i	-0.0042 + 0.0061i	0.0057 + 0.0246i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 35r2

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 35

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.5717	0.5008	99.0682	0.7990	0.8732	0.6139
2	11.6994	0.3312	98.5093	1.0268	1.0350	**Modal Density**
3	11.4442	0.2586	96.4567	0.8315	0.9266	0.8760
4	13.2454	0.2964	99.3221	0.8551	0.9656	**File Name**
5	13.5868	0.2622	97.5091	0.9663	0.9235	analy_green_35r2
6	14.4799	0.2646	98.5027	0.5446	0.4532	



Mode 1	Mode2	Mode 3
0.0199 - 0.0061i	-0.0152 + 0.0247i	-0.0032 + 0.0063i
0.0371 - 0.0117i	-0.0188 + 0.0308i	0.0091 - 0.0239i
0.0294 - 0.0094i	0.0171 - 0.0271i	0.0079 - 0.0204i
0.0181 - 0.0056i	0.0210 - 0.0330i	-0.0009 + 0.0017i
0.0198 - 0.0068i	0.0160 - 0.0253i	-0.0117 + 0.0279i
0.0249 - 0.0085i	-0.0093 + 0.0146i	-0.0168 + 0.0394i
Mode 4	**Mode 5**	**Mode 6**
0.0024 - 0.0056i	0.0592 - 0.0107i	-0.0260 + 0.0202i
-0.0129 + 0.0327i	-0.0155 + 0.0028i	0.0110 - 0.0084i
0.0150 - 0.0380i	-0.0097 + 0.0019i	-0.0117 + 0.0088i
-0.0065 + 0.0164i	0.0447 - 0.0086i	0.0339 - 0.0240i
-0.0223 + 0.0561i	-0.0167 + 0.0037i	-0.0194 + 0.0141i
0.0149 - 0.0375i	-0.0141 + 0.0022i	0.0129 - 0.0097i

System Information
System: Green Band (45.34 N/m)
PZT Coupling: Off
Mistuning: Set 36

Data Acquisition Information
Block Size: 4096
Number of Blocks: 8
Span: 500
Input Channel Range: 0.03
Source Range: 9
Chirp: 8 to 14 Hz for 4096 points

Analysis Information
Block of Data: 5000:5:32768
Hankel Matrix: 250X120
Singular Value Cut Off: 30

Mode	Freq. (Hz)	Zeta (%)	EMAC	Infinity Scale	Four Scale	MAC Scale
1	10.1832	0.5420	98.9423	0.6947	0.7659	0.7604
2	11.6441	0.3111	99.5014	1.1342	1.2992	**Modal Density**
3	10.8381	0.2748	97.3794	0.7326	0.7967	1.0151
4	12.7219	0.2988	98.8821	0.7640	0.8920	**File Name**
5	14.0738	0.3344	99.0051	0.7758	0.6066	analy_green_36
6	14.4555	0.2754	98.3141	0.6256	0.5902	

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Vita

Second Lieutenant Amy M. Cox was born on 15 August 1974 in Akron, Ohio. She Graduated from Archbishop Hoban High School in 1992 and entered undergraduate studies at the University of Cincinnati in Cincinnati, Ohio. She graduated with a Bachelor of Science in Mechanical Engineering in June of 1997. She received her commission on 14 June 1997 through the Air Force ROTC program.

In August of 1997 she began her first assignment as a direct accession to the Air Force Institute of Technology. Her next assignment is to Undergraduate Space and Missile Training at Vandenberg AFB, CA.

Permanent address: 1159 Jeanie J Avenue
Akron, Ohio 44310

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Amy M. Cox, 2nd Lieutenant, USAF

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Air Force Institute of Technology
2950 P St, Bldg 640
WPAFB, OH 45433-7765

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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NA Major Brian Sanders
801 N. Randolph Street, Room 732
Arlington, VA 22203-8451
(703) 696-7259

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Advisor - Captain Greg Agnes, ENY
Gregory.Agnes@afit.af.mil
(937) 255-6565 ext. 4317, DSN 785

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13. ABSTRACT *(Maximum 200 words)*
Cyclic structures, such as antenna arrays, are significantly impacted by slight changes to system periodicity. Manufacturing errors of 5% or less can result in drastic changes to a structure's modal behavior. This change in modal behavior may result in the focusing of modal energy to individual substructures of the system. Poor modal identification can result in poorly designed control systems, resulting in shape control and pointing issues for space antennae. Additionally, modal energy localization may damage individual system components due to unanticipated levels of cyclic loading, leading to high cycle fatigue.

In this study, the effects of varying the levels of system mistuning on mode localization is investigated. A test article representative of a space antenna has been constructed and its modal properties determined for various levels of both mistuning and inter-structure coupling. Also, two simple numerical models have been considered and Monte Carlo simulations have been conducted with various levels of mistuning and inter-structural coupling for each. The objective is to determine the probability and severity of system localization as a function of the system substructure imperfections. Additionally, reduction of mode localization through the addition of passive control to the system by way of piezoceramic materials is investigated.

14. SUBJECT TERMS
Mode Localization, Cyclic Structures, Monte Carlo, Space Antennae, Compressor Blades, Space Structures, Piezoceramic, Vibration

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